THE PRACTICAL MAGAZINE WITH THE PROFESSIONAL APPROACH

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Elektor Electronics

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Fast AF power amplifier
Time-signal receiver
Portable MIDI keyboard
Bus interface for LCD screens
Harmonic enhancer
μP-based multimeter
Mains signalling
A dish for Europe

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Elektor Electronics

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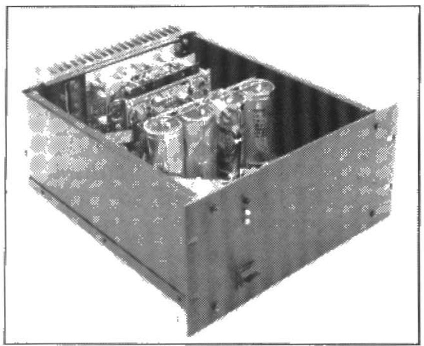

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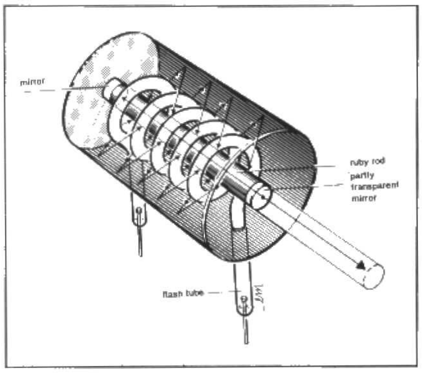

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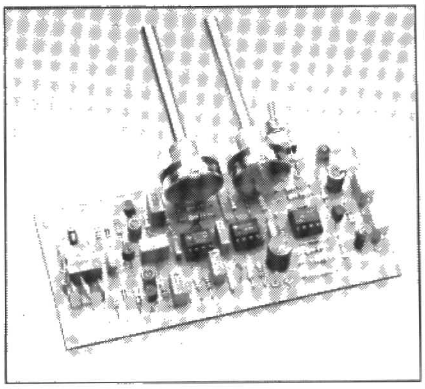

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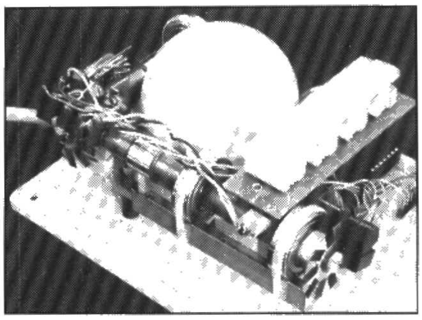

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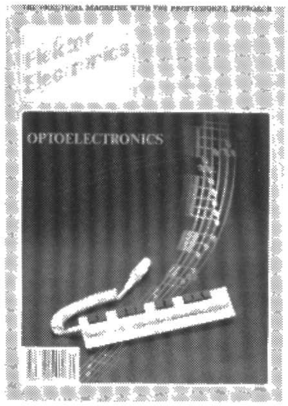

Front cover

A recently introduced IC makes a dream of many electrophonics enthusiasts come true: to build their own MIDI keyboard from a handful of components. The portability of the keyboard described in this issue makes it ideal for first-aid testing of MIDI equipment. Moreover, in conjunction with a microprocessor, it can be used for practising, composing, and editing musical pieces in places where a full-size keyboard would be cumbersome to use.

STAR WARS IN EUROPE?

It is alleged that the British public is as keen to invest in satellite television equipment as it was in video recorders a decade or more ago. The reasons for this are said to be that the public wants more TV channels and, above all, more choice of programmes. Whether this keenness is real or just a ruse of manufacturers to convince us all (and themselves) that it exists will be seen early next year when more programmes and inexpensive equipment to receive them will become available.

This month, Arianespace willing and able, Astra, the communications satellite owned by Luxembourg's Société Européenne des Satellites—SES — will be launched. After a settling-in period, this satellite will, from early February, beam television pictures to most of Europe.

The likely success of Astra has been enhanced by the failure of Germany's direct broadcast satellite (DBS), TV-SAT1, the complete and baffling silence around France's TDF1 (which should have been launched more than a year ago), and the lateness of Britain's high-power BSB satellite (now due to be launched towards the end of next year).

What really made things hum in Betzdorf (SES's headquarters in Luxemburg), however, was last summer's action by two men of vision who realized the enormous possibilities on offer by that gap in the market: Mr Rupert Murdoch and Mr Alan Sugar.

Mr Murdoch, the managing director of News International, has taken a 10-year lease on three of Astra's medium-power channels, and an option on a fourth, for his Sky Television, which already operates Sky Channel.

Mr Sugar, the chairman of Amstrad, has announced that in the coming year his company will build a million 60-cm dishes and television receiver adaptors that will allow people to tune in to Astra. The Amstrad equipment should start appearing in high-street shops by next spring at a retail price of under £ 200. Its installation should cost not more than £ 50. It will, therefore, be possible to watch Sky Television's three or four programmes for under £ 250.

Flies in the ointment might be individual European governments' interference in what their citizens will be allowed to watch, and the endeavours by the EEC and the Council of Europe to harmonize national regulations governing television. In our view, standards are much better left to the television broadcasting industry than to an outside regulatory body.

It should be emphasized that Sky Television's programmes will be free to receive. Their costs are borne by advertisers, just as those of the terrestrial programmes of the ITV companies. Other channels beamed down by Astra are expected to be encrypted. Such channels can only be watched on television receivers fitted with a pay-TV decoder.

Technically, the interesting point about the Sky Television channels is that they will be transmitted in the now ageing PAL format, whereas BSB is committed to transmitting in D-MAC. The MAC format will make possible improvements to television reception like stereo sound, additional commentary and data channels, and high-definition (larger picture, better resolution).

It is as well to forget the myth, engendered by some marketing people, that to receive MAC format transmissions a new type of television set is needed. As with all satellite TV reception, an adaptor is required, that's all. Production of MAC adaptors can commence soon, since Philips and Plessey expect to have the necessary decoding chip in volume production by January.

The Philips-Plessey decoding chip can be used with all the MAC formats envisaged so far, whereas that of ITT, the other company in this field, is designed for use only with D-MAC and D2-MAC. It remains a mystery that BSB has committed itself to the ITT set.

It will be interesting to see which way the British public wil go: the conventional and somewhat dated way with Sky Television, or the progressive, new-technology way of BSB. Both will be possible with existing sets. Adaptors, dishes and installations will be comparable in cost. It will, no doubt, be a revealing battle.

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LOGIC FAMILIES COMPARED

by Pete Chown

A brief look at the most important characteristics of recently introduced logic families, and the way in which they can be interfaced to one another.

Today, there exists a bewildering variety of logic families, and the rate at which new families are introduced and older ones become obsolete is perplexing to many. Metal-gate CMOS and standard 74 series TTL are now reaching the end of their useful life. Low power Schottky (LS) TLL is often still the first choice, although this family is now being superseded by HC-MOS. The continued use of of LS and S (high-speed) TTL probably results from lack of information about the alternatives. It is not enough to say that LS TTL does the job, however, because alternatives offer reduced power consumption.

The reason for the existence of so many different types of logic integrated circuit is that there is always a trade-off between speed and power consumption. The graph in Fig. 1 shows speed plotted against power. The modern logic families are those nearest to the bottom left, the point which would represent the ideal logic device, offering instantaneous operation at a power consumption of nought. The devices shown in the graph tends to form a line moving between the axes, showing different trade-offs between speed and power. The older devices, LS, 74, 4000 and S, appear above this line. Among the new families is ALS-TTL, Advanced Low-power Schottky, offering devices which are faster and more economical as regards power consumption than pure LS-TTL versions.

High-speed CMOS

The new 74HC and 74HCT series of silicon-gate CMOS devices offer speeds equivalent to LS-TTL, but with negligible power consumption. The 74HC device is the most useful, as it consumes least power, and offers the best range of output voltages for driving external devices (maximum output low voltage $V_{OL}=0.1$ V; maximum output high voltage $V_{OH}=4.9$ V). The problem comes with their inputs. It is here that HC and HCT devices are different. Although +2.4 V might seem a strange value to mean logic high, standard 74 series TLL can give exactly that in the worst case. This level is, however, outside the specifications for HC devices. IC Manufacturers have been aware of this, and have developed HCT devices by changing the inputs of HC types, so that the worst-case TTL logic high level will be accepted. Full compatibility of HCT with LS-TTL is thus achieved at the cost of a small increase in the power consumption.

HC and HCT devices are excellent for applications where low power and high noise immunity are important design considerations. The quiescent current consumption of an HC-MOS gate is about 0.0025 μW, increasing to about 170 μW at 100 kHz. Silicon-gate CMOS is the superior family when a high fan-out is required, since one output can drive about 1000 inputs. Many devices in the 74 LS-TTL family can practically be replaced by corresponding HCT devices as pin-compatible replacements.

It is easy to become over-excited about the very fast devices, although these will probably have far more impact on us in years to come, probably becoming what LS-TTL is today. We can, however, look forward to getting rid of noisy fans, and to lifting the lid of our PC without the usual blast of hot air.

There are two device families that fall between the ones discussed. These are the 74AS/74ALS series and the FAST® series. These two families are really rivals from different manufacturers — ALS is made by Texas Instruments, and FAST® by Fairchild and Motorola. The 74AS and 74ALS series offer a substantial reduction in power consumption over the 74S and 74LS series respectively. The fan-out is doubled, propagation delays have been considerably reduced, and the maximum bistable frequency has been increased to 200 MHz.

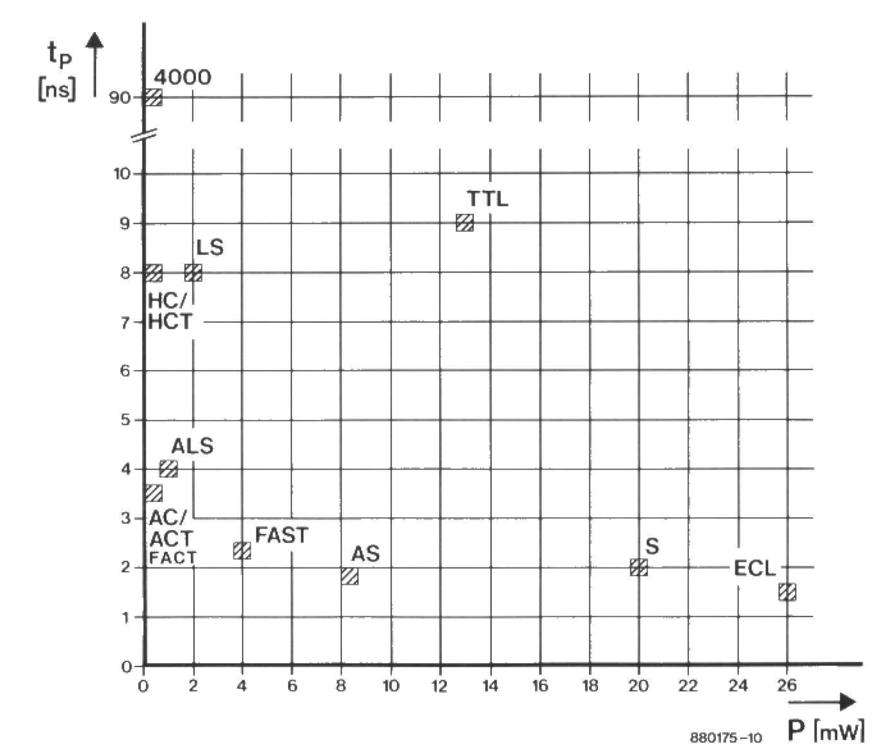


Fig. 1. Speed-power relationships of a number of commonly used logic families.

Interfacing logic families

One of the reasons that designers have been reluctant to use the new logic families is that they are worried about interfacing these devices to existing circuits. The rules for interfacing are quite simple. Many devices are designed to be compatible without any external device. Most others simply need a resistor. The overview in Table 1 gives information on interfacing a number of logic families. The actual value of the pull-up resistor (when required) is chosen to lie roughly between the low value and the high value, which are calculated as follows:

$$R_{low} = \frac{V_{CC} - V_{OL(max)}}{I_{OL} + n I_{IL}} \ [\Omega]$$

where
V_{CC} = supply voltage;
$I_{OL(max)}$ = maximum output low voltage;
I_{OL} = maximum sink current of driving device;
n = number of device inputs being driven;
I_{IL} = input current to driven device when input is low.

$$R_{high} = \frac{V_{CC} - V_{IH(min)}}{n I_{IH} - I_{OH}} \ [\Omega]$$

where
$V_{IH(min)}$ = minimum input high voltage;
I_{IH} = input high current;
I_{OH} = output high current.

It will be found that NMOS does not normally need a resistor because this would have a very high value. Not surprisingly, therefore, circuits work well without one. Table 2 lists some commonly used logic families and their parameters, allowing resistance values to be worked out. The resistor should obviously be inserted pulling up to Vcc. To choose the correct values to use in the above formulae, take the output parameters for the driving gate, and the input parameters for the driven gate.

Table 1. Interfacing guidelines

Vcc (Vdd) of driving and driven device is assumed equal.

Any two bipolar families:	should be compatible
HC to any bipolar:	should be compatible
Bipolar to HC:	pull-up required*
HCT to bipolar:	should be compatible
Bipolar to HCT:	should be compatible
HCT to NMOS:	should be compatible
NMOS to HCT:	normally compatible, but should be checked.

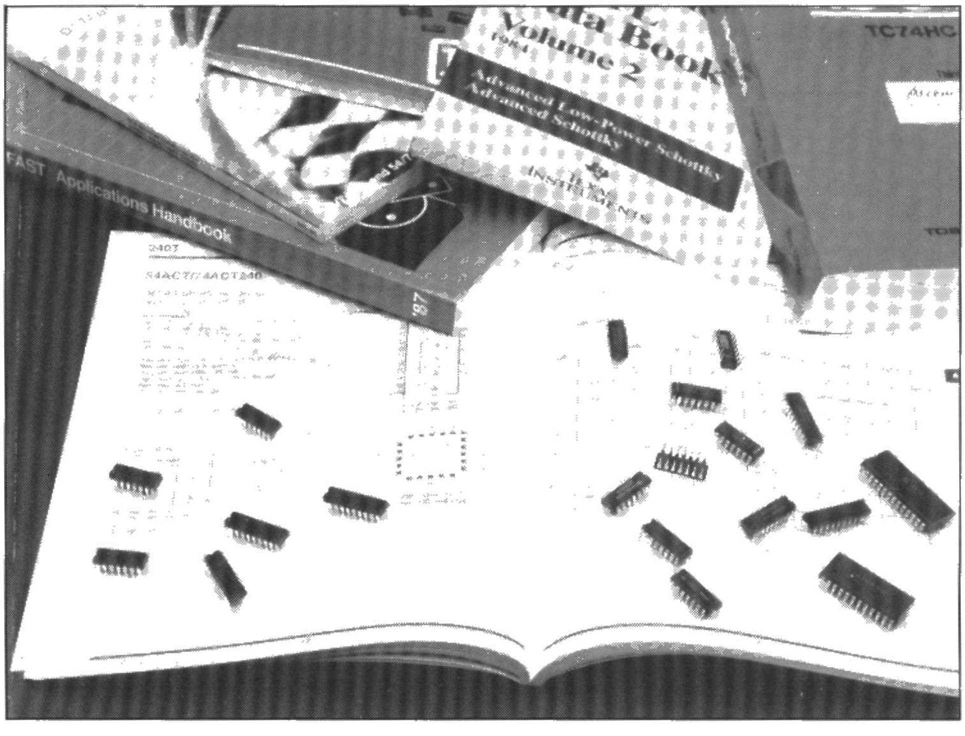
*Calculate value of pull-up resistor from formulae in text.

Table 2.

Parameter	74	74HC	74LS	74AS	74ALS	Unit
$V_{IH(min)}$	2.0	3.5	2.0	2.0	2.0	V
$V_{IL(max)}$	0.8	1.0	0.8	0.8	0.8	V
$V_{OH(min)}$	2.4	4.9	2.7	2.7	2.7	V
$V_{OL(max)}$	0.4	0.1	0.4	0.4	0.4	V
$I_{IH(max)}$	40	1	20	200	20	μA
$I_{IL(max)}$	−1.6	−0.001	−0.4	−2	−0.1	mA
$I_{OH(max)}$	−0.4	−4	−0.4	−2	−0.4	mA
$I_{OL(max)}$	16	4	8	20	4	mA

Conclusion

If you think the logic market is complex now, it will be even more so in a few years' time, because gallium-arsenide (Ga-As) devices promise operating speeds of around 4 GHz. These new devices will be around in parallel with FACT (Fairchild Advanced CMOS Logic) and existing TTL for a good time, because they will initially be so expensive. The ACT family, like HCT, is fully LS-TTL compatible, while AC gives basically the same drive problems as HC. Both new series are typically 2 to 3 times faster than LS-TTL or HCMOS. It should be noted that AC and ACT devices have a different supply pinning than LS-TTL, while the number of logic functions currently available is limited to certain bus drivers, and encoders/decoders. The range of AC/ACT devices is expected to entend considerably, however, in the next year or so.



Good documentation is essential for anyone designing, analyzing and testing circuits based on devices from the new logic families.

INFRA-RED REMOTE CONTROL FOR STEPPER MOTORS

Many audio purists balk at the use of an electronic volume control, but would still like to upgrade a home-made preamplifier with remote control. This can be accomplished by using a good-quality potentiometer, a stepper motor, and the simple, yet versatile, infra-red transmitter and receiver described here.

One particularly interesting application of the proposed infra-red remote control system is the actuating of the volume potentiometer in a high-quality audio preamplifier, such as the one described last month. Basically, the potentiometer is operated by a small stepper motor, whose direction of travel is controlled by means of pulses emitted by a hand-held infra-red transmitter.

Infra-red transmitter

The circuit diagram of this part of the remote control system is shown in Fig. 1. Simple data encoding is used to keep the cost of the circuit as low as possible. The direction of travel of the stepper motor fitted at the receiver side is determined by the width of the pulses supplied by two monostable multivibrators, MMV_1 (70 μs) and MMV_2 (470 μs). The pulse frequency, and hence the motor speed, is set with P_1 in oscillator N_3-N_4. Buttons S_1 and S_2 form the volume up/down controls because they determine whether MMV_1 or MMV_2 drives the output transistor, T_1. The pulsating infra-red light beam is emitted by series-connected IREDs D_1-D_2-D_3.

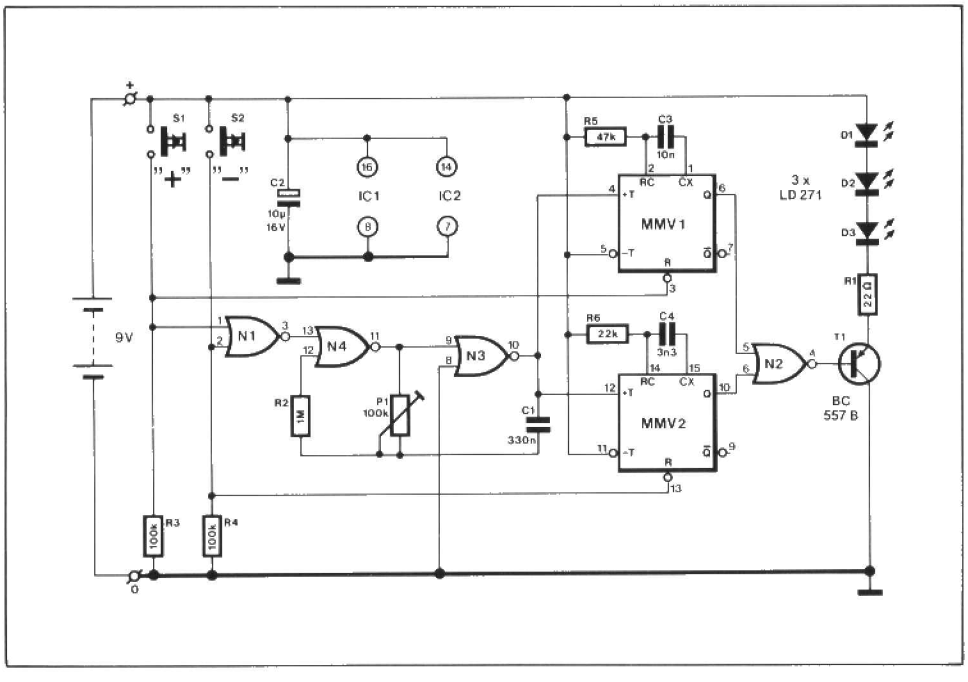


Fig. 1. Circuit diagram of the hand-held infra-red transmitter.

Receiver and motor driver

Photodiode D_4 in Fig. 2 was selected for optimum sensitivity in the part of the infra-red spectrum covered by the sender diodes (see also Ref. 1.) The photocurrent generated by the incident infra-red light is magnified and converted to a voltage by opamp A_2, which drives detector A_1 via high-pass C_5-R_{13}. This filter serves to eliminate interference caused by sunlight and hum superimposed on light by electric bulbs. The detection threshold of comparator A_1 is kept low at about 10 mV (R_{10}-R_{12}) to ensure adequate sensitivity. Feedback resistor R_{11} provides the necessary hysteresis to prevent jitter and spurious step pulses being generated when A_1 toggles.

Each received pulse triggers both MMV_3 and MMV_4, and is compared to reference pulses of 220 μs supplied by MMV_4. Received pulses are applied direct to the clock input of stepper motor driver IC_5, whose DIR (direction) input is controlled by the output of MMV_4. This makes the direction of travel of the stepper motor dependent on the length of the received pulses, relative to that of the reference pulses.

Features:

- Infra-red remote control link with a range of up to 8 metres.
- Forward/reverse control of stepper motors.
- Adjustable motor speed.
- Drives a variety of 2-stator, unipolar, motors.
- Maximum drive capability: 4 A per phase.
- Supply voltages:
  receiver logic: 9.5-18 VDC;
  stepper motor: max. 18 VDC;
  transmitter: 9 V PP3 battery.
- Simple, low-cost design.

Although the stepper motor driver Type SAA1027 (SGS/Philips Components) is capable of supplying stator currents of up to 500 mA, power drivers (T_3-T_6) are added to prevent excessive dissipation, and to allow the use of motors that require more current. The flyback diodes in the power stage should be fast-recovery types (1N493x series, or BYV27). The use of the ubiquitous 1N4001 is not recommended unless the total stator current is known to remain well under 1 A. Power resistors R_{16} and R_{17} may be used to achieve a rudimentary kind of current drive of the stator windings in the motor — more on this under 'The power supply'.

Provision has been made for manual operation, at the receiver, of the volume control. This is achieved by T_2-R_{14} automatically interrupting the base current for the driver stage in the SAA1027 when no pulses have been received for about 0.1 s. Series transistor T_2 then interrupts the hold torque for the motor, so that the potentiometer spindle can be operated manually. This type of control guarantees low overall dissipation because there is no quiescent hold current. Certain motors do require a continuous hold current, however. These can still used with the present circuit simply by omitting T_2 and fitting a wire link between the connections provided for its collector and emitter terminals.

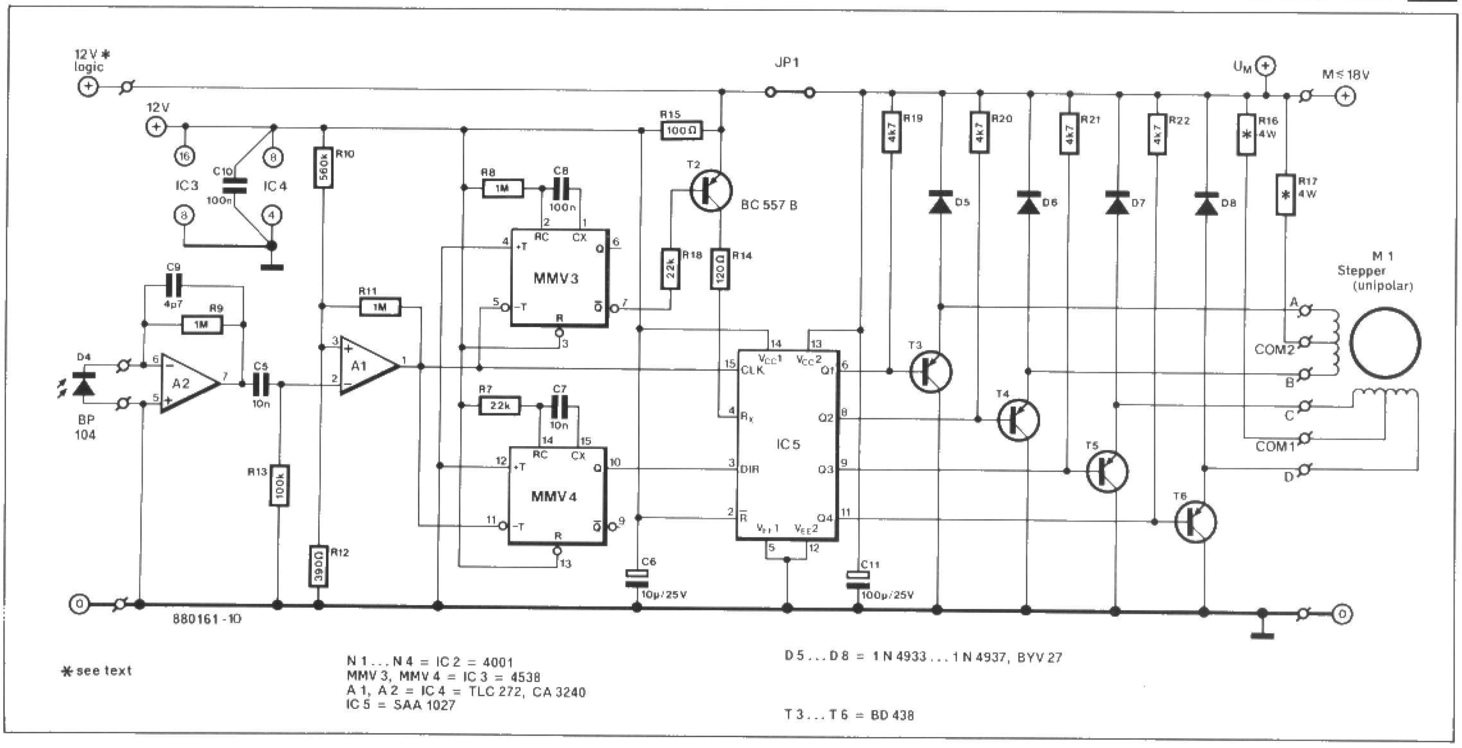


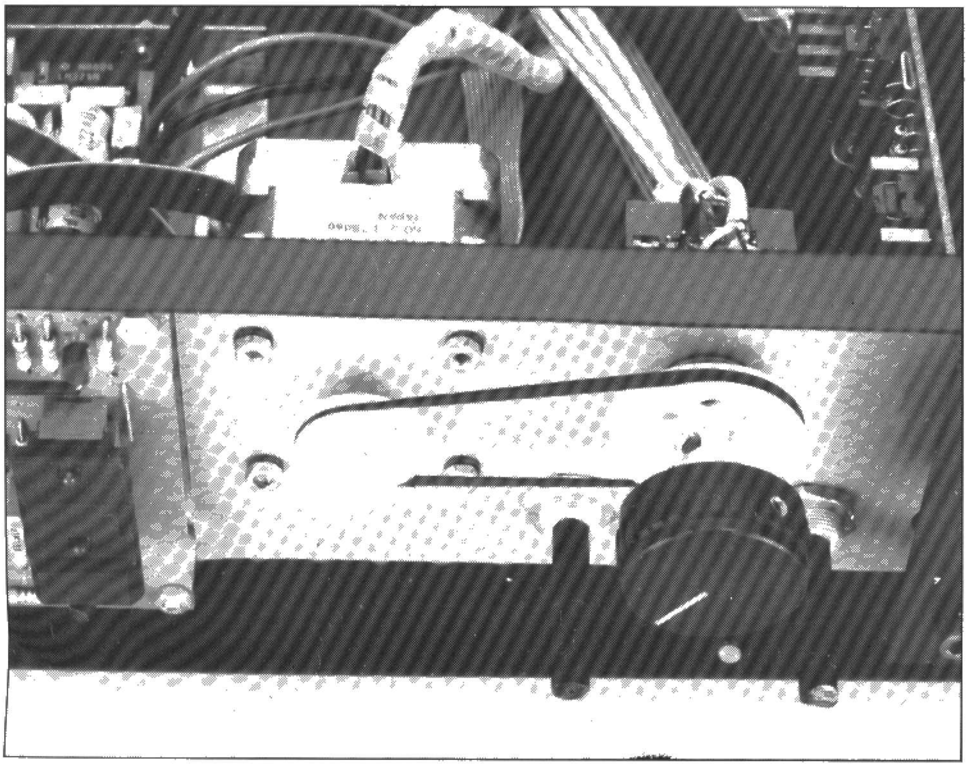
Fig. 2. Circuit diagram of the infra-red receiver, pulse decoder and stepper motor driver.

The power supply

The IR transmitter is powered by a 9 V PP3 battery. An on/off switch is not required because the quiescent current consumption of the circuit is negligible at a few nano-amperes. This rises to a few milli-amperes when either of the two buttons is pressed. The actual current consumption then depends on the setting of P_1.

The type of supply required for the receiver depends mainly on the environment in which this circuit is used. The logic circuitry can operate from a supply voltage between 9.5 V and 18 V. It will be clear that the supply for the motor is laid out in accordance with the type used. A 12 V motor is ideal because it allows powering the driver stage and the logic circuitry from a common supply, connected to terminals U_M and ground (fit jumper JP_1). The logic supply is decoupled with the aid of R_{15}-C_6. Fit wire links in positions R_{16} and R_{17} when the motor used requires voltage drive.

Many stepper motors are 5 V types. Where a relatively powerful type is used, it is recommended to dimension the motor supply for 5 V (connect to U_M



Motorized volume control built into the high-quality preamplifier described last month.

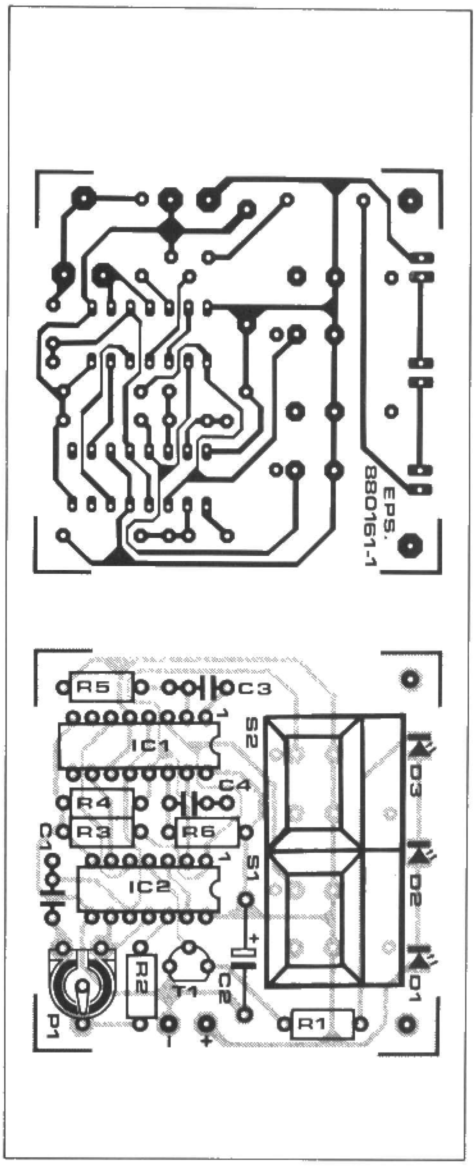


Fig. 3. Printed circuit board for the transmitter. Together with a PP3 battery, it fits exactly in a Type 222 enclosure from Heddic.

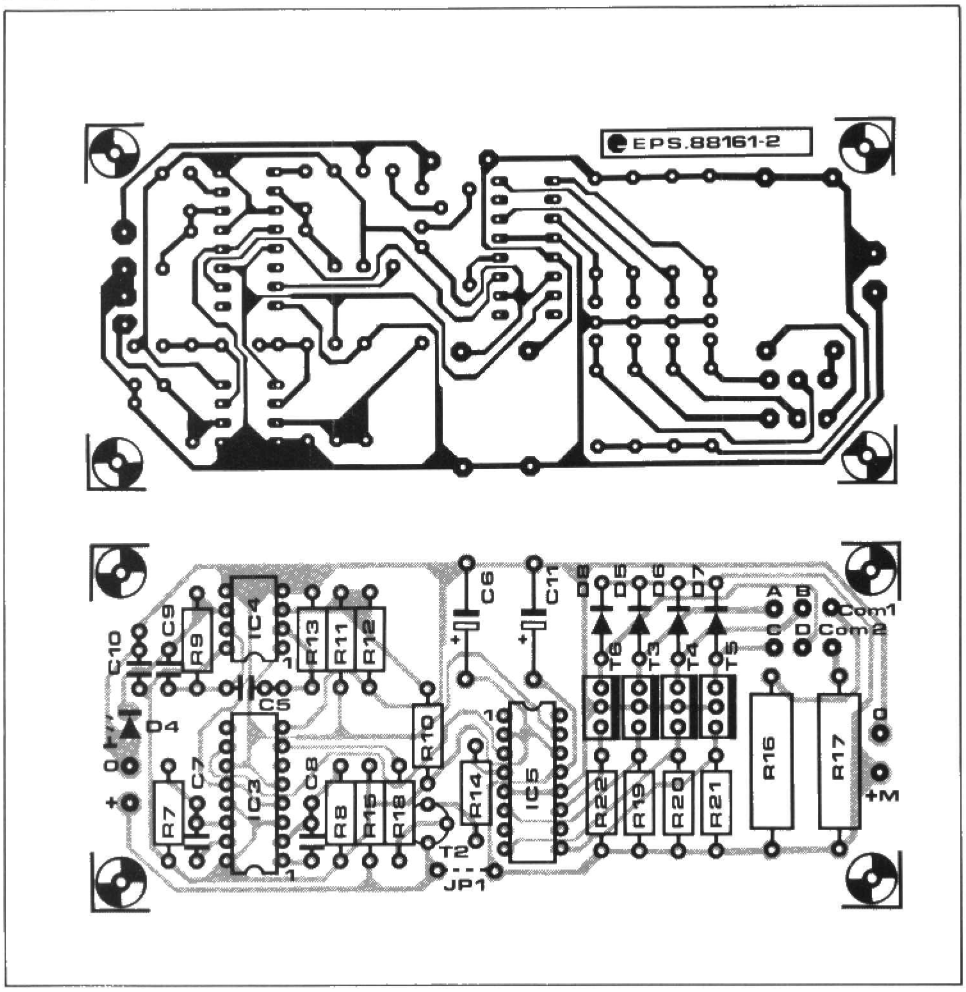


Fig. 4. Printed circuit board for the receiver.

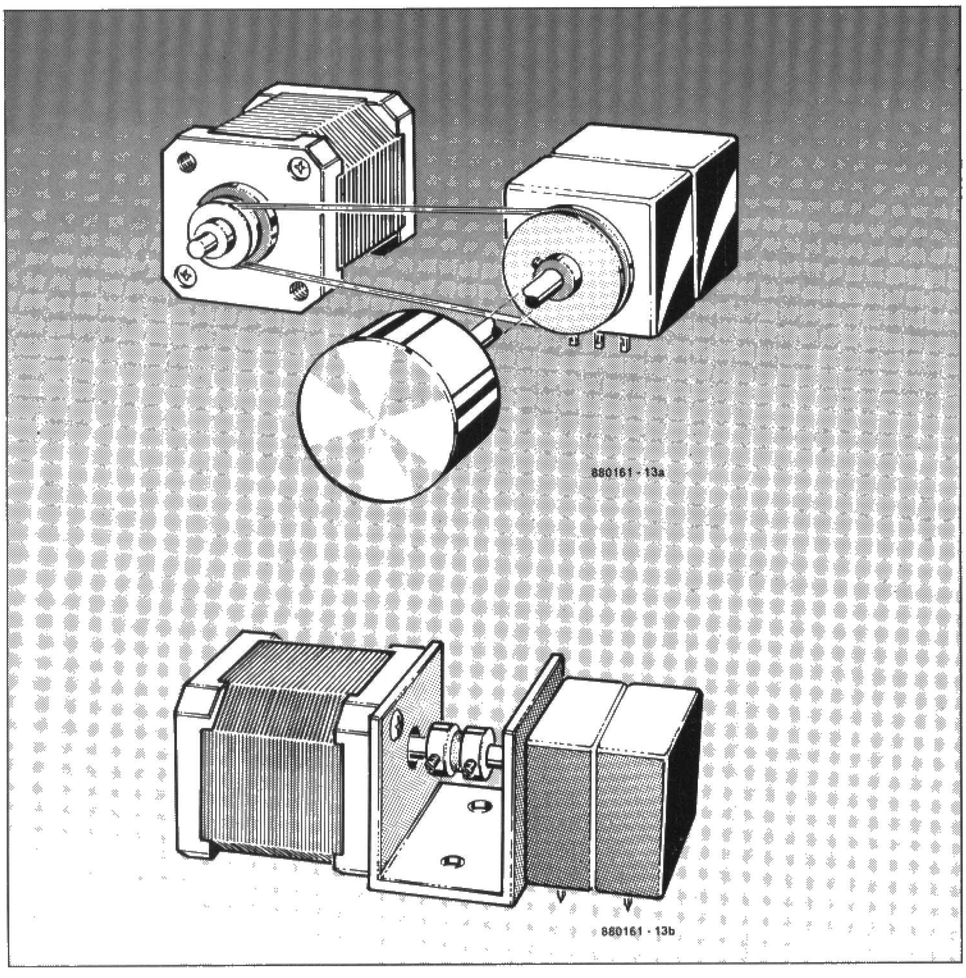


Fig. 5. Two suggestions for coupling the stepper motor spindle to that of the potentiometer.

Parts list

Resistors (±5%):
R_1 = 22R
R_2;R_8;R_9;R_{11} = 1M0
R_3;R_4;R_{13} = 100K
R_5 = 47K
R_6;R_7 = 22K
R_{10} = 560K
R_{12} = 390R
R_{14} = 120R
R_{15} = 100R
R_{16};R_{17} = 4 W resistor; value depends on stepper motor used.
R_{18} = 22K
R_{19} . . . R_{22} incl. = 4K7
P_1 = 100K preset H

Capacitors:
C_1 = 330n
C_2 = 10μ; 16 V
C_3;C_5;C_7 = 10n
C_4 = 3n3
C_6 = 10μ; 25 V
C_8;C_{10} = 100n
C_9 = 4p7
C_{11} = 100μ; 25 V

Semiconductors:
D_1;D_2;D_3 = LD271*
D_4 = BP104*
D_5 . . . D_8 incl. = 1N4933/4+/5/6/7 or BYV27+
T_1;T_2 = BC557B
T_3 . . . T_6 incl. = BD438
IC_1;IC_3 = 4538
IC_2 = 4001
IC_4 = TLC272 or CA3240
IC_5 = SAA1027+

Miscellaneous:
S_1;S_2 = Digitast switch (ITW or ITT/Schadow).
3 off plastic reflectors* for D_1-D_3.
PCB Type 880161 (not available ready-made through the Readers Services).

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and ground). Fit wire links for R_{16} and R_{17}, but do not fit JP_1 — connect the 12 V supply to terminals + and 0 (close to D_4 on the PCB). Where a relatively small stepper motor is used, R_{16} and R_{17} are dimensioned to reduce U_M from 12 V to the voltage required. This is convenient because it allows the complete receiver plus motor driver to be powered from a single supply. Small, 200-step, 5 V motors used in disk drives are sometimes offered by surplus stores. These motors give excellent results with $R_{16} = R_{17} = 39\ \Omega$; 4 W (stator current = 200 mA).

It shoud be noted that the circuit can only drive unipolar motors. These normally have 6 connecting wires, but there are also 5-wire types in which the centre taps of the two stator windings (COM1; COM2) have been connected internally.

Constructional hints

Construction of the transmitter and receiver on the printed circuit boards shown in Figs. 3 and 4 should not cause problems. The transmitter is fitted in a hand-held ABS enclusure with integral battery compartment. The 3 IREDs are fitted with ready-made reflectors to increase the range of the transmitter.

To prevent it seeing light from bulbs or fluorescent tubes fitted to the ceiling, the photodiode in the receiver should be mounted in a short tube whose inside is painted matt black. If the diode is fitted on to the front panel of the audio equipment, it should be connected to the receiver board by means of shielded wire. In some cases, it may be necessary to decrease the sensitivity of the receiver to prevent it being triggered by ambient light. This can be achieved by increasing the value of R_{12} to, say, 560 Ω.

The use of a stepper motor that draws more than about 1 A necessitates cooling of the power transistors in the receiver by clamping them together with the aid of 3 small, 2.5 mm thick, pieces of aluminium and a central M3 bolt.

Figures 5a and 5b provide suggestions for coupling the stepper motor spindle to that of the potentiometer. Cog-wheel systems should not be used because they are damaged quite easily by the vibration of the stepper motor. A rubber or nylon belt as used in cassette recorders, or a strengthened O-ring, is perfect because it allows manual control of the potentiometer as discussed earlier.

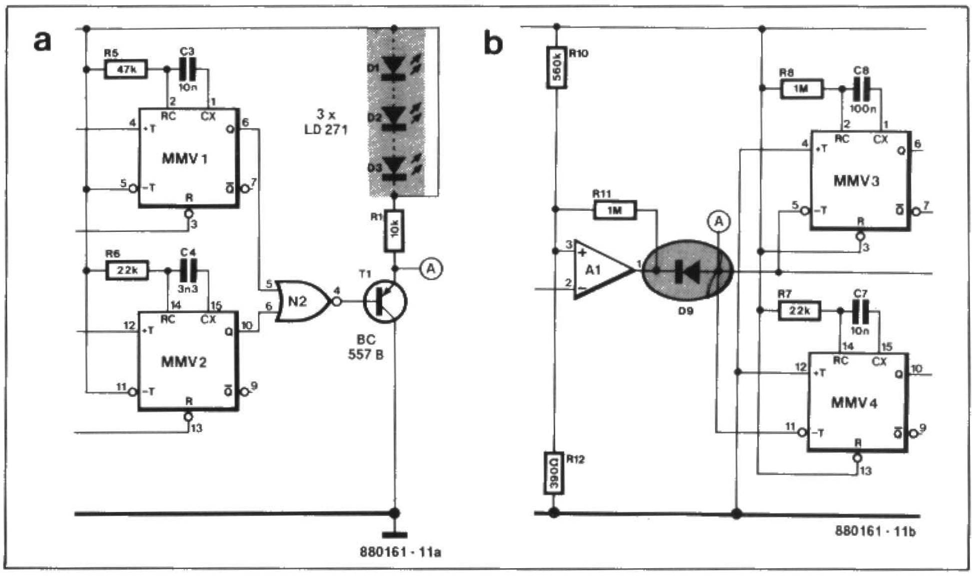


Fig. 6. Modifications to transmitter and receiver to enable manual volume control when the stepper motor and potentiometer spindles are coupled as shown in Fig. 5b.

The stepper motor and the volume potentiometer may also be secured on to a common U-shaped piece of aluminium as shown in Fig. 5b. In this arrangement, the spindles are coupled direct. Manual control is still possible, however, when the transmitter is duplicated and fitted close to the receiver. The modifications to the transmitter and the receiver to achieve local control are shown in Figs. 6a and 6b. In the transmitter, the (shaded) IREDs are replaced with a wire link, R_1 is replaced with a 10 kΩ type, and the points marked A in the transmitter and receiver are interconnected.

Diode D_9 is inserted between the comparator output and the trigger inputs of the monostables. Together with the T_1 in the transmitter, it forms a wired-OR function. The 'local' volume up/down controls, S_1 and S_2, are fitted on to the front panel of the equipment.

References:

1. Long-range infra-red transceiver. *Elektor Electronics* November 1987, p. 36-45. Contains a useful background to infra-red light communication.

NEWS

Anglo-US transatlantic paging

British Telecom's 80 per cent stake in the US Metrocast national paging company will not only give it access to the major US paging networks, but will also lead to a transatlantic Anglo-US paging service being established next year.

British Telecom • 81 Newgate Street • LONDON EC1A 7AJ.

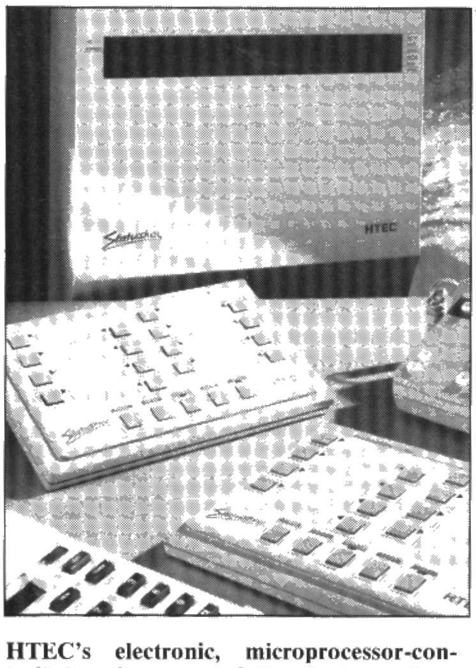
Tape circuits simplify board production

Marconi Electric Devices has started pilot production with a higher yielding, low-cost method of making hybrid circuits, the miniature electronic assemblies carrying chips and other components. The new method enables circuit boards up to 15 cm wide to be built from layers of glas ceramic tape with components moulded inside recesses to provide tough solid circuits that do not need expensive metal protection.

Marconi Electronic Devices • Hargreaves Road • Groundwell Industrial Estate • SWINDON SN2 5BE.

Telephone interface

A cost-effective, easy-to-use telephone system, capable of interfacing up to 16 lines with up to 16 consoles (allowing a choice of telephone instrument) has been introduced by HTEC. It is an electronic, microprocessor-controlled replacement for the electromechanical key-and-lamp system.



HTEC's electronic, microprocessor-controlled replacement of the electromechanical key-and-lamp telephone system.

Ideal for emergency control rooms, sales organizations, travel agents, financial and dealing rooms, the system allows any one extension to answer calls on any one of 16 lines, with multiple line-hold and transfer, extension-status indication, ground loop/timed break, recall, and indication of longest call waiting.

HTEC • 303-5 Portswood Road • SOUTHAMPTON SO2 1LD.

Audio-visual control unit

Electrosonic have introduced the APU Turbo, a compact audio-visual presentation control unit capable of controlling up to 24 projectors. It combines a hi-fi stereo sound replay system with a multi-image dissolve unit that controls the projectors and auxiliary functions, such as houselights.

Electrosonic • 815 Woolwich Road • LONDON SE7 8LT.

LFA-150: A FAST POWER AMPLIFIER (PART 1)

from a basic idea by A. Schmeets

This first of a two-part article describes the design of a power amplifier that makes use of very fast ring-emitter transistors and delivers up to 150 watts into 8 ohms. A feature of the design is the low negative-feedback factor.

Although commercial high-quality audio power amplifiers have made use of multiple-emitter and ring-emitter transistors for some time, these devices have not been easily obtainable for private purposes. That situation has changed, fortunately, and a number of importers can now supply them on a small-quantity basis.
Multiple-emitter transistors consist of a number of identical transistors connected in parallel on one chip. The ring-emitter transistor is a power transistor with a special chip structure for the base, collector and emitter regions. These transistors are the fastest and most linear devices for use in audio power amplifiers.
High-quality audio power amplifiers are still based on discrete designs, although good-quality power amplifier modules have become available over the past year or so. However, where absolute top quality is wanted, based on an uncoventional design, there is no other way than the use of discrete transistors.
The present design hinges on low open-loop gain, which guarantees minimal transient-intermodulation (TIM) distortion and thus the best possible sound quality. The bandwidth is sufficiently large to ensure minimal phase shift over the entire audio range, which again aids the sound quality.

Power output (20 Hz-20 kHz; THD = 0,5%)	150 W into 8 ohms 200 W into 4 ohms
THD (1 kHz)	< 0.01% (1 W) < 0.01% (10 W) < 0.04% (100 W)
(20 Hz – 20 kHz)	< 0.025% (1 W)
Frequency response (1 W)	1 Hz – 1 MHz (unweighted)
Power bandwidth	1 Hz – 350 kHz (unweighted)
Phase error (20 Hz – 20 kHz)	< 5°
TIM (75 W; 50 Hz: 7 kHz; 4:1)	< 0.05%
Slew rate	> 50 V/μs (unweighted)
Open-loop bandwidth	10 kHz
Open-loop amplification	2,300
Output impedance	< 0.05 ohm
Input sensitivity	1.1 V r.m.s.
Signal-to-noise ratio	> 110 dB

Design philosophy

The design of an AF power amplifier can go two ways. The first uses a very high open-loop gain combined with a very large negative-feedback factor; the second, a low open-loop gain and a consequent smaller negative-feedback factor. Most audio power amplifiers belong to the first category, because in that design it is easy to achieve low harmonic distortion. However, that design also has a serious shortcoming. When the input signal is fairly large and of a frequency that lies outside the open-loop bandwidth of the amplifier, there is a likelihood, owing to the high open-loop gain, of some of the internal amplifier stages becoming saturated. This results in strong bursts of intermodulation that are clearly audible and sound like crossover distortion. Note that the audio signal variations are maximum around the zero crossing points, so that saturation is most likely about these points. These problems may be avoided by reducing the open-loop gain. This increases the open-loop bandwidth, so that the likelihood of the frequency of the input signal lying outside the open-loop bandwidth is much smaller. Of course, this also causes an increase in the total harmonic distortion (THD), but that is not really a serious problem. The human ear is nowhere near as sensitive to THD as to TIM and crossover distortion. In other words, an amplifier with 0.3% THD and 0.003% TIM will in practice always sound better than one with 0.003% THD and 0.3% TIM.
Apart from low open-loop gain, the various stages of a good-quality amplifier need to have a large bandwidth to ensure, if possible, an open-loop bandwidth greater than the audio range. It is, fortunately, possible to optimize both the bandwidth and the phase behaviour where necessary in the amplifier with the aid of lead-compensation (networks that locally increase the amplification above a given frequency).
Another important aspect is the fre-

quency compensation that limits the open-loop bandwidth (the so-called lag-compensation). This compensation determines the slew rate of the amplifier and must, therefore, be applied as close to the input as possible to ensure that the input signal is limited before it is fed to the amplifier stages.

In many amplifiers, the negative-feedback factor for a.c. signals is different from that for d.c. signals, which is normally achieved with the aid of a capacitor. It is true that this puts less of an onus on the stability of the circuit, but it may give rise to problems, particularly since the capacitor often has such a large value that an electrolytic type (!) is used. With correct design and good temperature stability throughout the amplifier, there is no need for the two factors to be different.

Practical considerations

Although the foregoing, on the face of it, would lead to a near-ideal design, there are some practical problems. To start with, it is difficult to achieve low THD and low TIM in the same design: in practice, a compromise has to be sought. In the present design, this is found in an open-loop amplification of 2,300 and an open-loop bandwidth of 10 kHz. The amplification is sufficient to achieve acceptable THD figures. The goal of an open-loop bandwidth of 20 kHz or more proved impossible to achieve, however, in spite of extensive lead-compensation. Furthermore, the stability requirements meant severe limiting of phase shifts and this proved only possible by restricting the open-loop bandwidth to around 10 kHz. It should be noted, of course, that this is still an outstanding bandwidth: most commercial amplifiers with a high open-loop amplification (100,000 to 1,000,000) have an open-loop bandwidth of 30 to 50 or 60 Hz!

The lag-compensating network, which determines the bandwidth, is located between the branches of the first differential amplifier. It would have been possible to locate it between the inputs of that amplifier, but that would have meant taking back the feedback to the input also. And that in turn would result in the amplification becoming dependent, partly at least, on the characteristics of the preceding preamplifier.

To make it possible for the amplifier to be DC-coupled throughout (to keep the a.c. and d.c. gains equal), a double FET was found necessary at the input: not an inexpensive solution, but one resulting in very good stability. It is true that the gain of a FET combination is on the low side, but in this particular design that does not matter.

The slew rate in the practical design is kept to 50 V/μs. Again, this is on the safe side, because in the prototypes slew rates of around 100 V/μs were attainable.

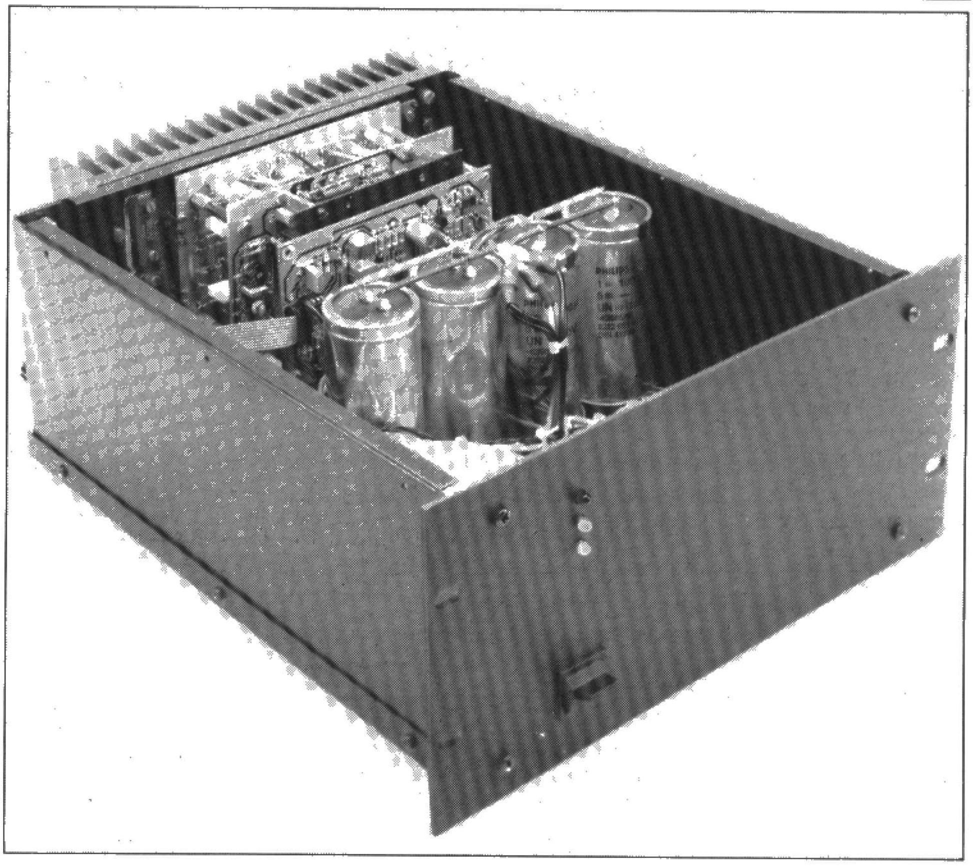


Fig. 1. General view of the LFA-150.

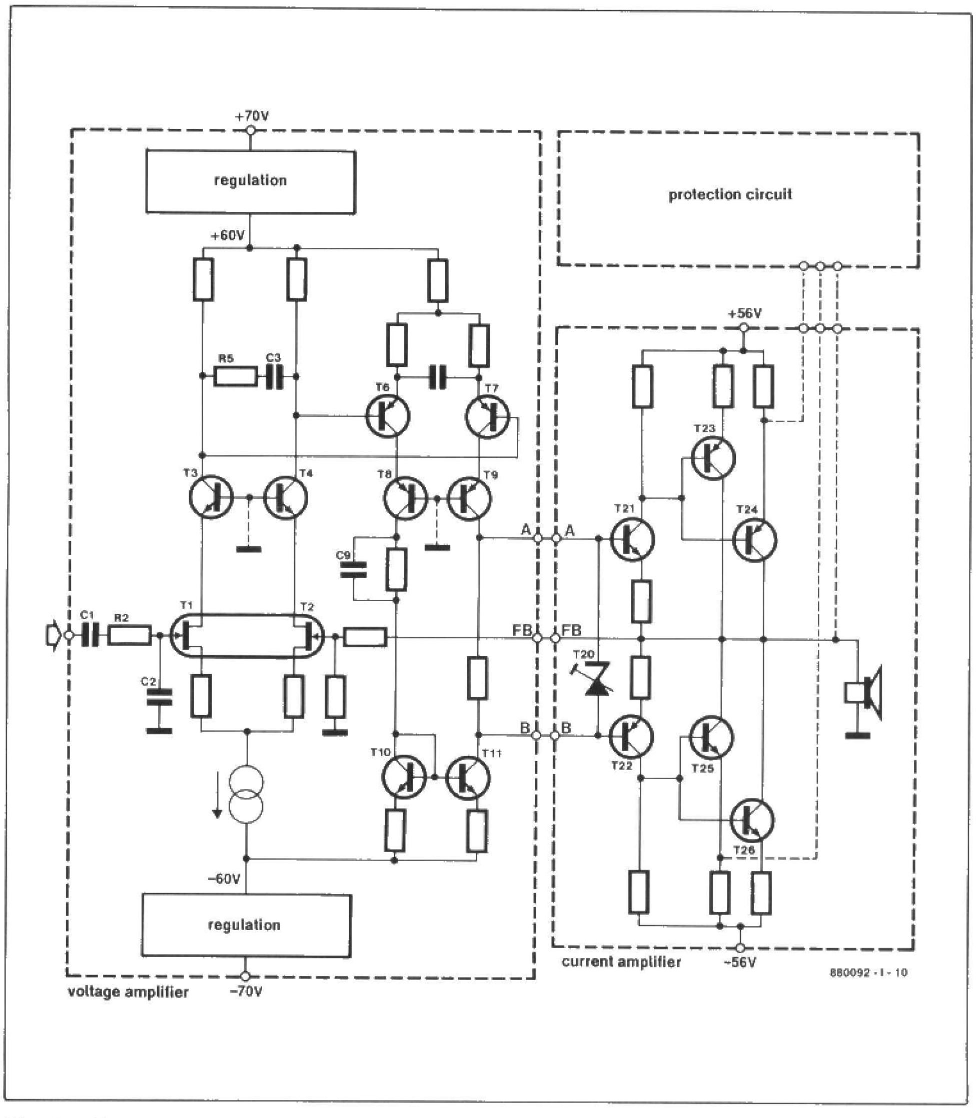


Fig. 2. Simplified circuit diagram of the LFA-150.

The design

The basic design may be assessed from the simplified circuit diagram in Fig. 2. It is split into two parts: a voltage amplifier and a current amplifier. The input of the voltage amplifier is formed by the dual FET already mentioned. The cascode circuit connected to the drains of the FETs not only enables the drain-source voltage of the FETs to be kept at a reasonable value, but also, more importantly, to eliminate to a large extent the internal drain-gate capacitance of the FETs, resulting in a substantial bandwidth.

The first differential amplifier is followed by another, which is, however, constructed from discrete transistors and, moreover, is provided with a current mirror, T_{10} and T_{11}. The current mirror serves to provide a signal at B that is in phase with that at A.

Network R_5-C_3 provides lag compensation, while C_8 and C_9 provide lead compensation.

The current amplifier consists of a quiescent-current control around T20 and a symmetrical dual output stage, comprising a driver and two parallel-connected output transistors.

Noteworthy in the output stage is that the output transistors are not connected as emitter followers but in a so-called compound configuration. In this, a sort of darlington is created which, due to a large amount of internal negative-feedback, combines very low distortion with a low output impedance.

The stabilized power supply to the voltage amplifier is 4 V higher than that to the current amplifier, so that the voltage drop across the output transistors remains small, even at maximum drive.

Finally, the protection circuit serves to monitor the setting of the quiescent current level, the loudspeaker impedance, and the output current.

Circuit description

Each of the four unshaded parts in Fig. 3 is housed on a separate PCB. At the left is the voltage amplifier; beside it the current amplifier and protection circuit; and at the top right the auxiliary power supply.

Voltage amplifier. The input signal is applied to differential amplifier T_1-T_2 via C_1 (the only capacitor in the entire signal path) and low-pass filter R_2-C_2. The filter has a cut-off frequency of about 200 kHz. It serves to limit the bandwidth, and thus the slew rate, before the signal is amplified.

The differential amplifier is a dual FET housed in a metal case. The negative feedback voltage is applied to the gate of T_2.

Transistors T_3 and T_4 and the FETs

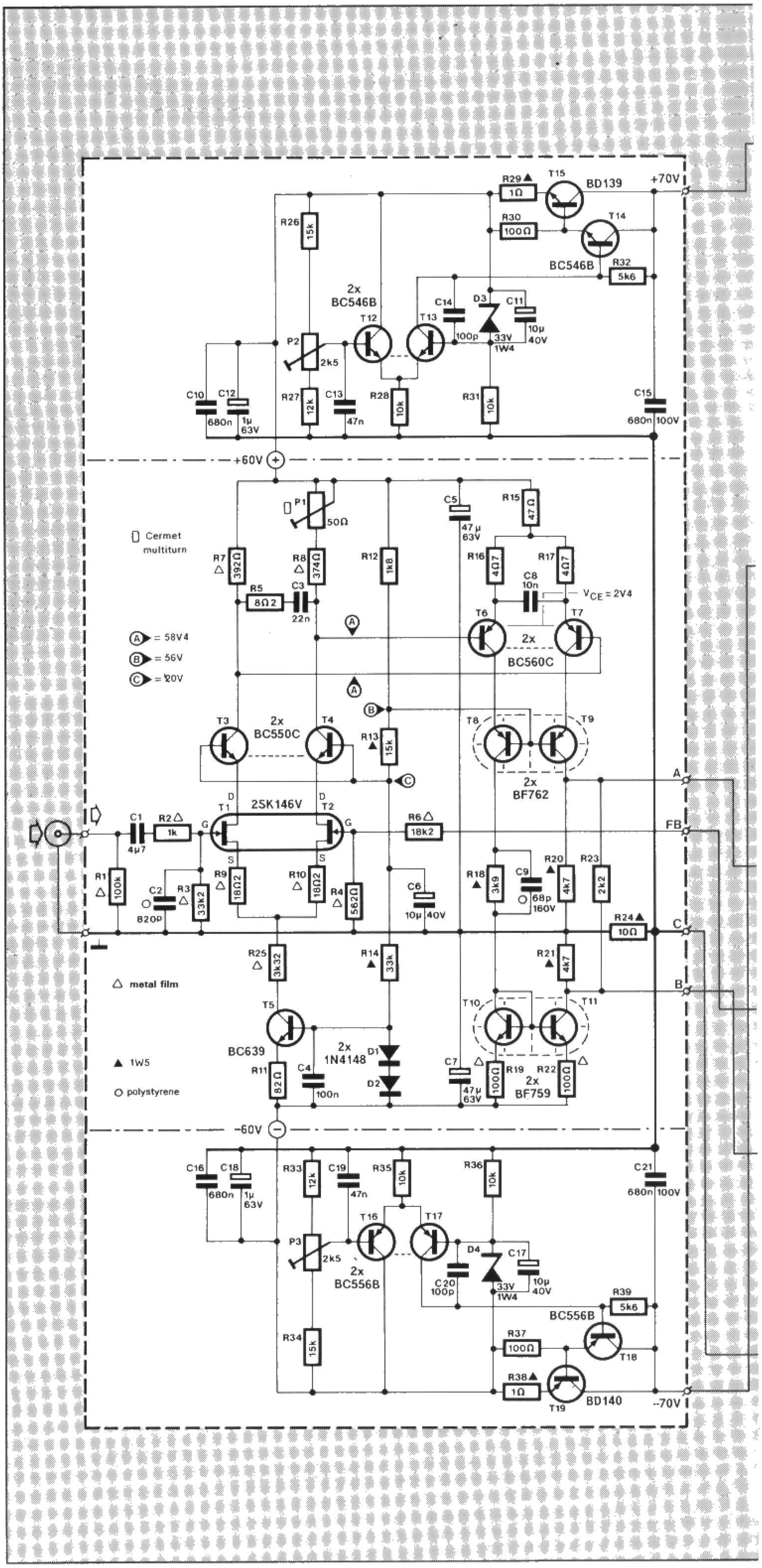
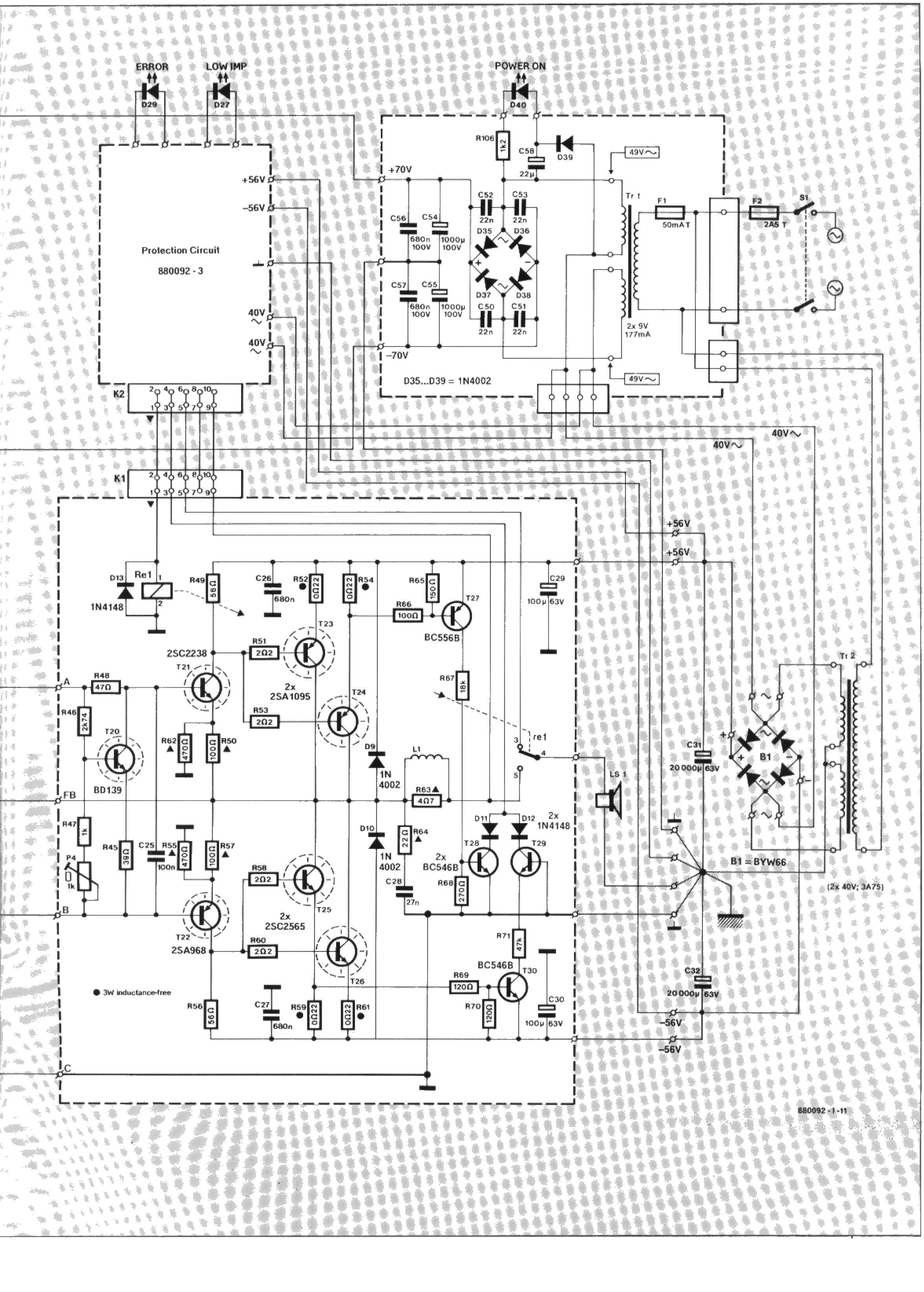


Fig. 3. Circuit diagram of the LFA-150.


ERROR
LOW IMP
POWER ON
D29
D27
D40
Protection Circuit
880092 - 3
+56V
-56V
40V
R106
1k2
C58
22µ
D39
49V~
+70V
-70V
C52
22n
C53
22n
C56
680n
100V
C54
1000µ
100V
D35
D36
D37
D38
C57
680n
100V
C55
1000µ
100V
C50
22n
C51
22n
Tr 1
F1
50mA T
F2
2A5 T
S1
2x 9V
177mA
D35...D39 = 1N4002
K2
K1
40V~
Re1
D13
1N4148
R49
56Ω
C26
680n
R52
0Ω22
R54
0Ω22
R65
150Ω
R66
100Ω
T27
BC556B
C29
100µ 63V
T23
2SC2238
R51
2Ω2
T21
2x
2SA1095
T24
R48
47Ω
A
R46
2k74
T20
BD139
R62
470Ω
R50
100Ω
R53
2Ω2
R67
18k
re1
D9
1N
4002
L1
R63
4Ω7
LS 1
FB
R47
1k
P4
1k
R45
39Ω
C25
100n
R55
470Ω
R57
100Ω
R58
2Ω2
T25
2x
2SC2565
D10
1N
4002
R64
22Ω
C28
27n
D11
D12
2x
1N4148
T28
T29
2x
BC546B
R68
270Ω
B
T22
2SA968
R60
2Ω2
T26
R71
47k
BC546B
T30
R69
120Ω
R70
120Ω
C30
100µ 63V
R56
56Ω
C27
680n
R59
0Ω22
R61
0Ω22
● 3W inductance-free
C
C31
20 000µ 63V
C32
20 000µ 63V
B1
B1 = BYW66
Tr 2
(2x 40V; 3A75)
880092 - I - 11

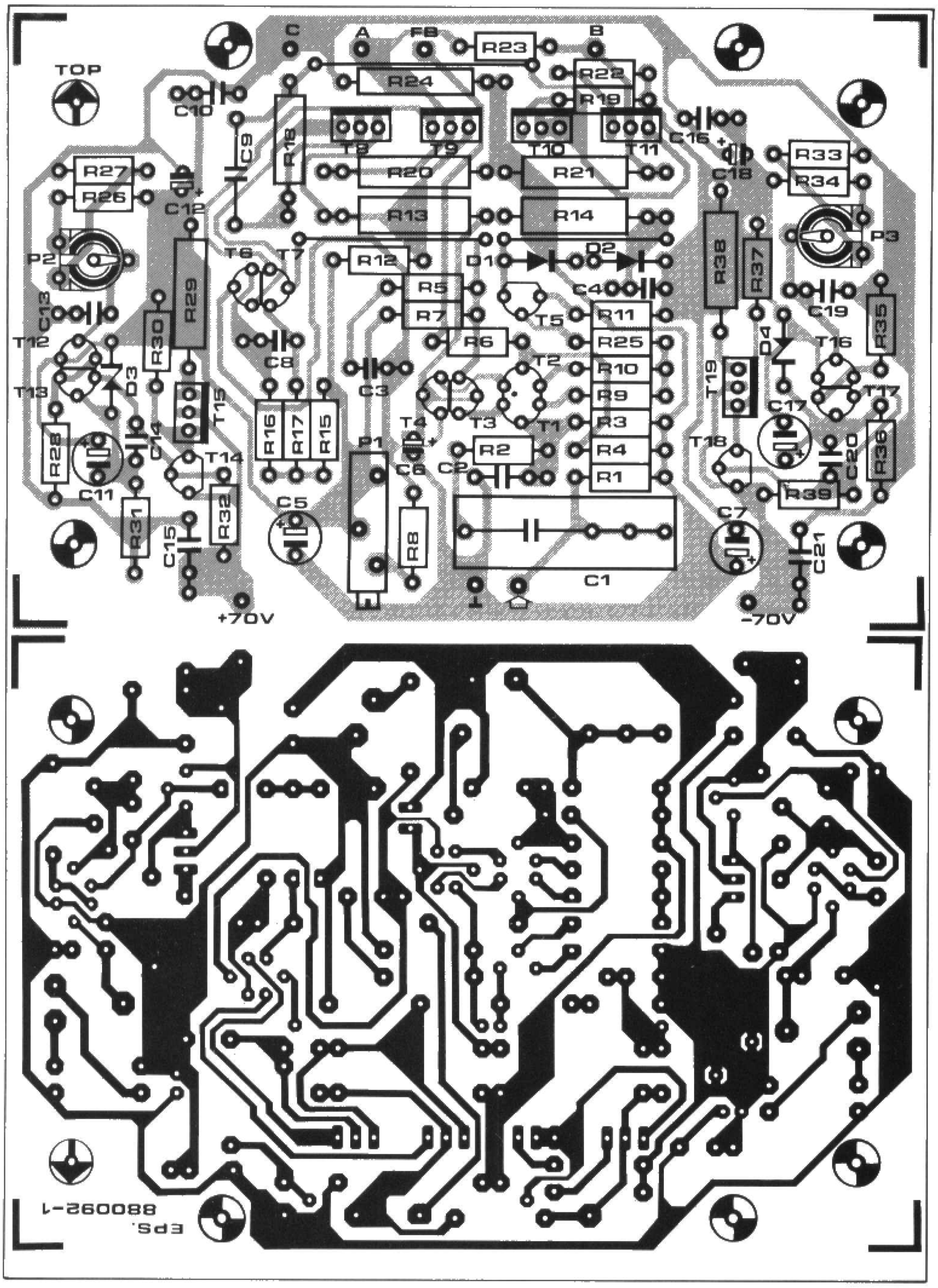


Fig. 4. PCB for the voltage amplifier.

Parts list

VOLTAGE AMPLIFIER BOARD

Resistors:
R_1 = 100K^{+}
R_2 = 1K0^{+}
R_3 = 33K2^{+}
R_4 = 562R^{+}
R_5 = 8R2
R_6 = 18K2^{+}
R_7 = 392R^{+}
R_8 = 374R^{+}
R_9;R_{10} = 18R2^{+}
R_{11} = 82R
R_{12} = 1K8
R_{13} = 15K; 1.5 W
R_{14} = 33K; 1.5 W type
R_{15} = 47R
R_{16};R_{17} = 4R7
R_{18} = 3K9; 1.5 W
R_{19};R_{22} = 100R^{+}
R_{20};R_{21} = 4K7; 1.5 W
R_{23} = 2K2
R_{24} = 10R; 1.5 W
R_{25} = 3K32^{+}
R_{26};R_{34} = 15K
R_{27};R_{33} = 12K
R_{28};R_{31};R_{35};R_{36} = 10K
R_{29};R_{38} = 1R0; 1.5 W
R_{30};R_{37} = 100R
R_{32};R_{39} = 5K6
P_1 = 50R multiturn preset (Cermet)
P_2;P_3 = 2K5 preset H

$^{+}$Metal film resistor

Capacitors:
C_1 = 4μ7; MKT
C_2 = 820p polystyrene/styroflex
C_3 = 22n
C_4 = 100n
C_5;C_7 = 47μ; 63 V
C_6;C_{11};C_{17} = 10μ; 40 V
C_8 = 10n
C_9 = 68p; 160 V; polystyrene/styroflex
C_{10};C_{16} = 680n
C_{12};C_{18} = 1μ0; 63 V
C_{13};C_{19} = 47n
C_{14};C_{20} = 100p
C_{15};C_{21} = 680n; 100 V

Semiconductors:
D_1;D_2 = 1N4148
D_3;D_4 = 33V; 1.4 W zener diode
T_1;T_2 = 2SK146V
T_3;T_4 = BC550C
T_5 = BC639
T_6;T_7 = BC560C
T_8;T_9 = BF762
T_{10};T_{11} = BF759
T_{12}...T_{14} incl. = BC546B
T_{15} = BD139
T_{16}...T_{18} incl. = BC556B
T_{19} = BD140

Miscellaneous:
PCB Type 880092-1 (see Readers Services page).

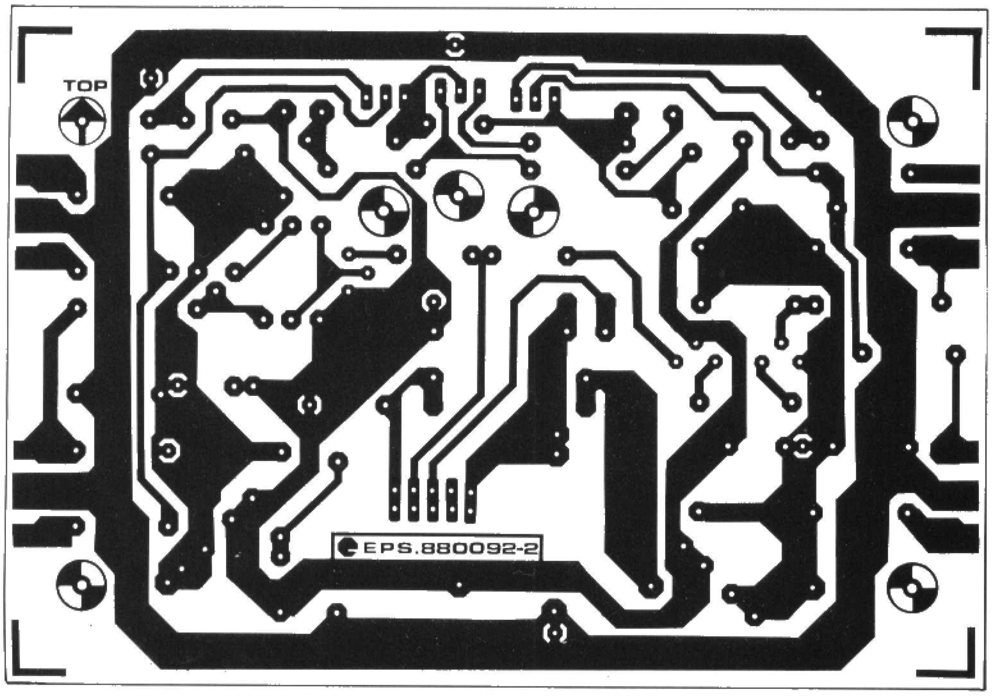


Fig. 5. PCB for the current amplifier.

Parts list

CURRENT AMPLIFIER BOARD

Resistors:
R_{45} = 39R
R_{46} = 2K74+
R_{47} = 1K0+
R_{48} = 47R
R_{49};R_{56} = 56R
R_{50};R_{57} = 100R; 1.5 W
R_{51};R_{53};R_{58};R_{60} = 2R2
R_{52};R_{54};R_{59};R_{61} = 0R22 non-inductive resistor
R_{55};R_{62} = 470R; 1.5 W
R_{63} = 4R7; 1.5 W
R_{64} = 22R; 1.5 W
R_{65} = 150R
R_{66} = 100R
R_{67} = 18K
R_{68} = 270R
R_{69};R_{70} = 120R
R_{71} = 47K
P_4 = 1K0 multiturn preset (Cermet)

+Metal film resistor

Capacitors:
C_{25} = 100n
C_{26};C_{27} = 680n
C_{28} = 27n; 250 V
C_{29};C_{30} = 100μ; 63 V
C_{31};C_{32} = 20,000μ; 63 V (can-type capacitor; not on PCB)

Semiconductors:
B_1 = BYW66 (not on PCB)
D_9;D_{10} = 1N4002
D_{11};D_{12};D_{13} = 1N4148
T_{20} = BD139
T_{21} = 2SC2238
T_{22} = 2SA968 T_{23};T_{24} = 2SA1095
T_{25};T_{26} = 2SC2565
T_{27} = BC556B
T_{28};T_{29};T_{30} = BC546B

Miscellaneous:
K_1 = 10-way straight header.
L_1 = 12 turns enamelled copper wire, dia. 1.5 mm; internal diameter approx. 15 mm.
Re_1 = V23127-B0006-A201 (24 V change-over relay; Siemens)
PCB 880092-2 (see Readers Services page).

form a cascode circuit: T_3 and T_4 maintain the drain potential, derived from divider R_{12}-R_{13}-R_{14}-D_1-D_2, at about 20 V. The amplification of the input stage is restricted to 3.5 by resistors R_9 and R_{10}. To keep the bandwidth at the output of the cascode circuit as large as possible, the values of collector resistors R_7 and R_8-P_1 are fairly low. The preset, P_1, serves to eliminate any inequalities in the d.c. operating points.

Lag compensation is provided by R_5-C_3. The capacitor determines the open-loop crossover point, while the resistor keeps the phase shift down.

The d.c. operating point of the FETs is set by a constant-current source around T_5.

Differential amplifier T_6-T_7, together with T_8 and T_9, also form a cascode circuit to keep the bandwidth as large as possible.

The output of T_8 is fed to the current amplifier via current mirror T_{10}-T_{11} and terminal B. The signals at terminals A and B are, therefore, in phase with one another.

Lead-compensation capacitors C_8 and C_9 serve to maximize the bandwidth of the second cascode circuit.

Current amplifier. The current amplifier consists of drivers T_{21} and T_{22} followed by power transistors T_{23}, T_{24}, T_{25} and T_{26}, which, as already mentioned, are connected in a compound configuration. This section also provides a small voltage amplification due to resistors R_{57} and R_{62}.

The power transistors are protected by diodes D_9 and D_{10} against any large negative voltage surges that may originate in the loudspeaker system. The d.c. operating point is provided by transistor T_{20}, which acts as an adjustable zener diode. This stage enables the setting of the voltage drop across T_{21}, R_{50}, R_{55}, and T_{22}, and thus that across resistors R_{49} and R_{56}, which determine the quiescent current of the power transistors.

Transistor T_{20} is mounted on the heatsink for the drivers and power transistors to guarantee good thermal feedback: this ensures that the quiescent current remains steady even when the temperature rises. The quiescent current is about 100 mA per transistor, so that the output stages can comfortably handle small signals in class A.

Boucherot network R_{64}-C_{28} ensures that the output is loaded even at high frequencies.

Inductor L_1 limits current surges caused by predominantly capacitive loads at the output.

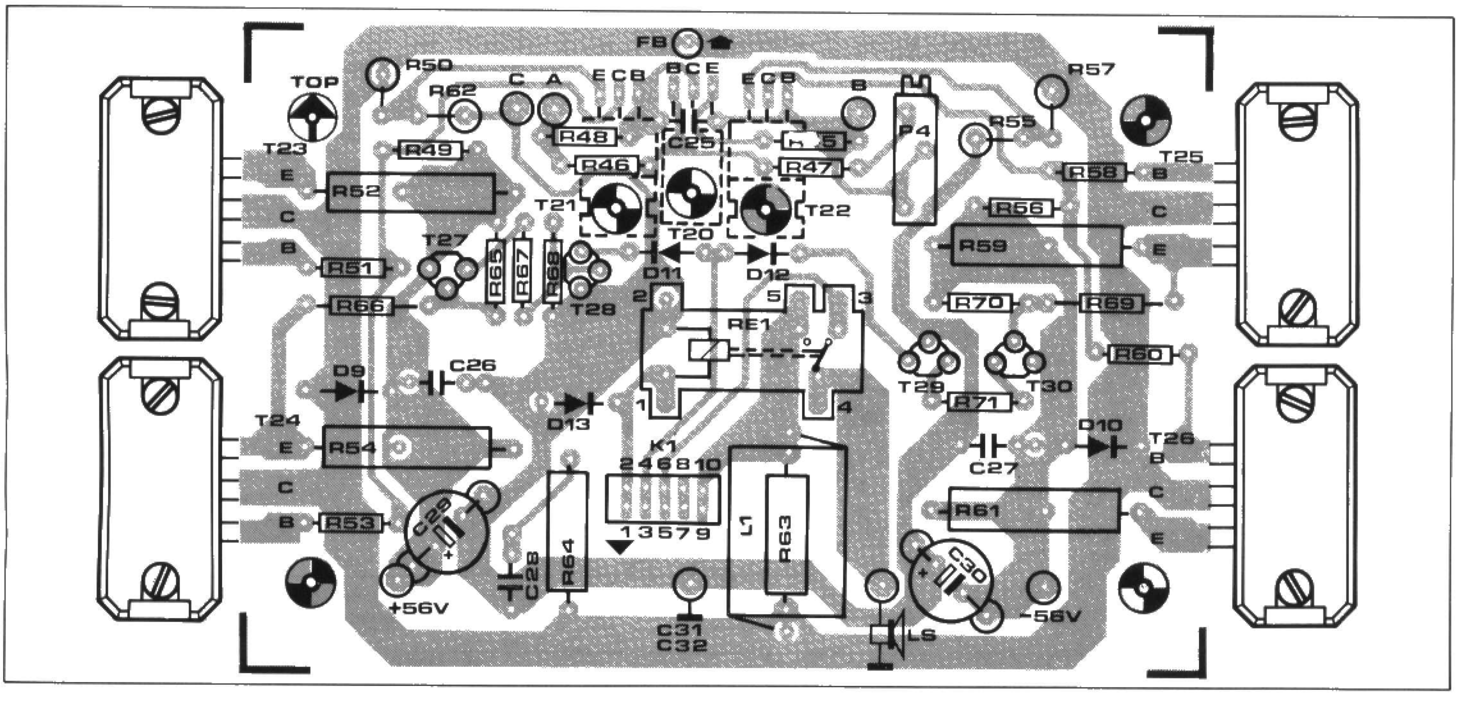
The signal at the collectors of the power transistors is fed back to the gate of T_2 in the voltage amplifier via R_6. The ratio R_6:R_4 determines the voltage amplification: with values as shown, this amounts to 3.5. The input sensitivity of the voltage amplifier is then 1.1 V r.m.s.

Power supply. The power supply uses two mains transformers in series, Tr_1 and Tr_2. Note that Fig. 3 shows the power supply for a mono amplifier.

Transformer Tr_2 is a heavy-duty toroidal type with a centre-tapped secondary: each half delivers about 40 V a.c. Full-wave rectification is effected by bridge rectifier B_1 and smoothing of the d.c. voltage is carried out by four 10,000 μF electrolytic capacitors: C_{31} and C_{32}. The open-circuit supply voltage for the power transistors is about ±57 V; at full load, this drops to around ±51 V.

The series connection of Tr_1 and Tr_2 provides a supply voltage of ±70 V for the voltage amplifier. This supply is regulated at ±60 V by discrete regulators T_{12} to T_{15} and T_{16} to T_{19} respectively.

A differential amplifier in each regulator compares the output voltage with a



zener-derived reference potential; any differences are eliminated by a darlington series regulator in the two supply lines. Presets P_2 and P_3 facilitate the setting of the respective voltage to their correct level.

Protection circuit. The protection circuit will be described next month, but its connections to the other parts of the circuit are already shown in Fig. 3.
The output relay is located on the current amplifier board to ensure the shortest possible loudspeaker connections.
Transistors T_{27} and T_{30} monitor the current through emitter resistors R_{54} and R_{59} respectively and, if necessary, actuate the protection circuit via T_{28} and T_{29}. This happens when the output current exceeds 10 A.

Practical design

The sub-division of the circuit over four PCBs makes the construction rather easier to keep under control. The construction details will be given next month, but Fig. 1 gives some idea what the LFA-150 looks like.
The PCBs have been designed in a way that makes it possible for three of them to be fixed together with the aid of suitable spacers. Only the PSU board is mounted by itself in the enclosure.
The drivers, power transistors and T_{20} are all screwed firmly to the heat sink with their terminals away from the heat sink. The current amplifier board is mounted on top of this arrangement (see Fig. 6), then the voltage amplifier board on top of that (see Fig. 7), and finally the protection board at the very top.
All connections carrying large currents on the current amplifier board have been kept as short as possible. This explains the rather strange position of the output relay at the centre of the board.

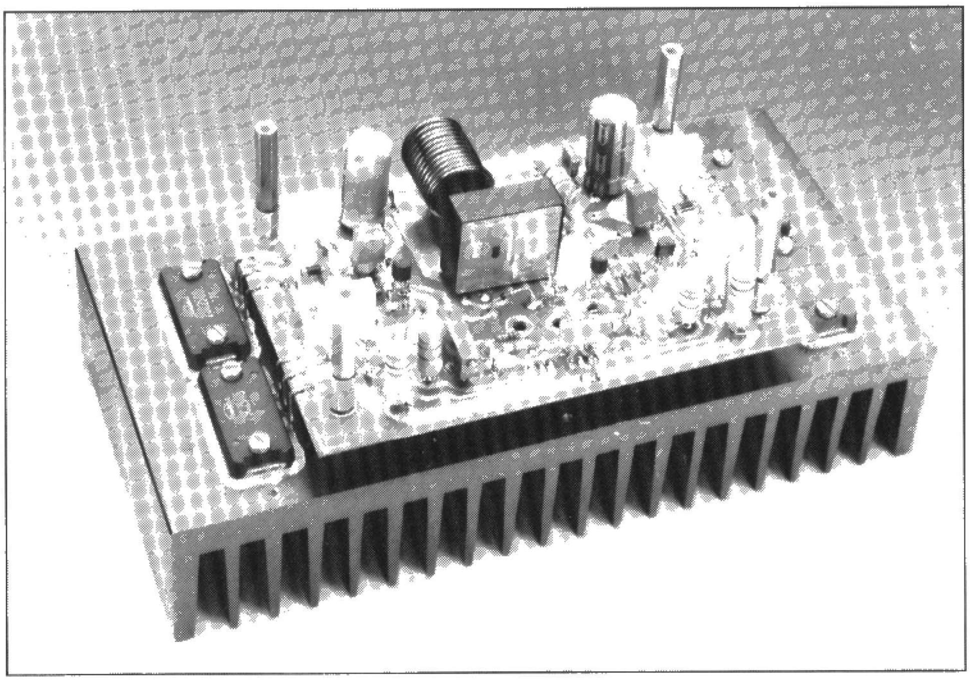


Fig. 6. After the drivers and power transistors have been fitted to the heat sink, the current amplifier board is mounted above with the aid of spacers.

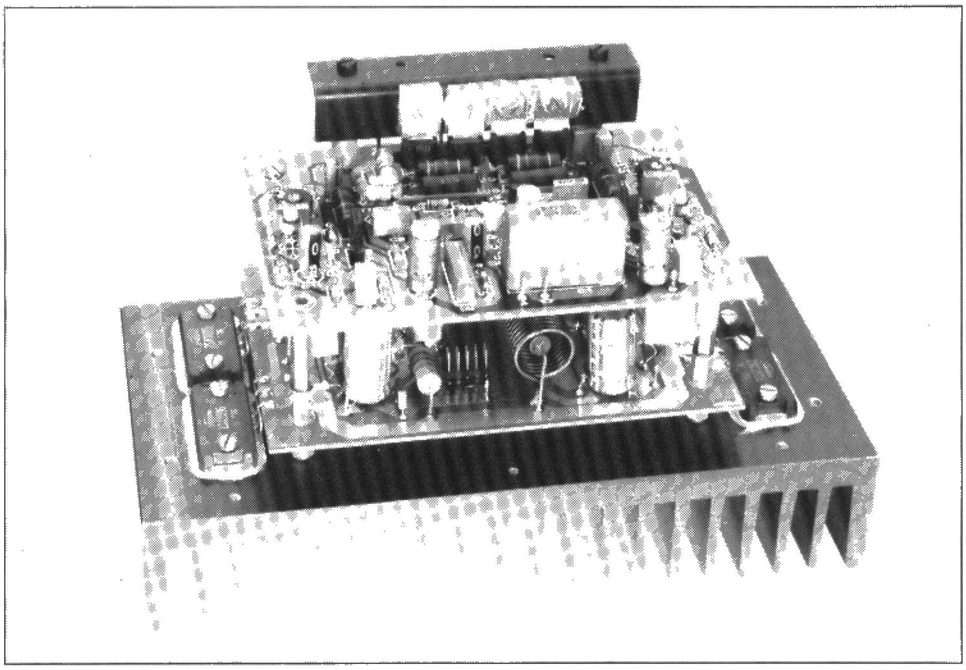


Fig. 7. The voltage amplifier board is mounted above the current amplifier board, again with the aid of suitable spacers.

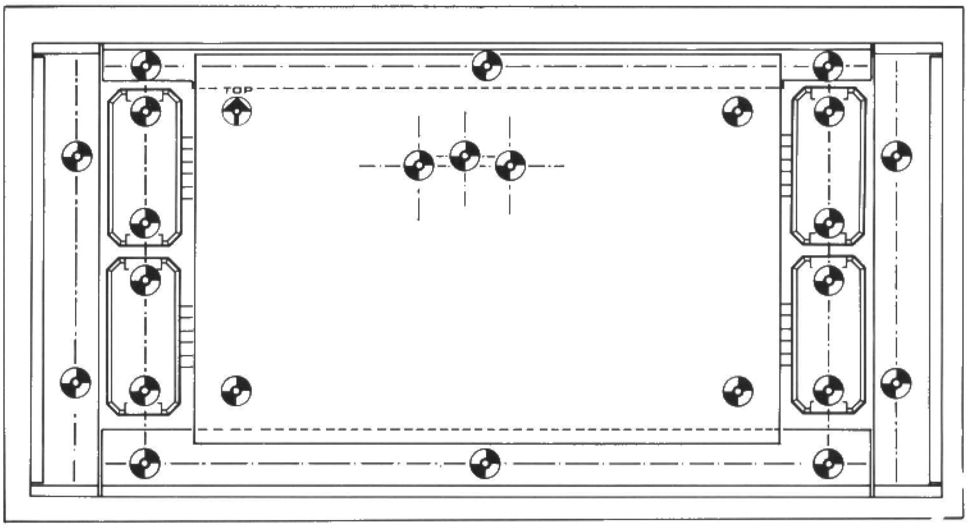


Fig. 8. Drilling diagram of heat sink.

MAINS SIGNALLING

by A.M. Karailiev

Mains signalling is a method by which signals can be superimposed on mains wiring for remote control of electrical equipment. Typical applications are the control of street lighting, space heating, energy management systems and many other control switching applications in domestic, commercial and industrial premises.

The operating principle of the proposed modulator is shown in Fig. 1. Two thyristors, Th_1 and Th_2, are connected in parallel across a variable inductor. Th_1 and Th_2 are controlled via optical fibres connected to the control centre. Normally, the thyristors are open, so that the total alternating supply current passes through them and the inductor. In this state, there is no modulation, since the modulation voltage, U_Ω, is nought. This changes when one of the thyristors is closed, since then $U_\Omega \geq 0.01U_\approx$ — the transmitter is sending a signal into the mains network. In the simplest case, the receiver detects U_Ω, and switches on a certain load, or group of loads. The second thyristor is included to provide a complementary-phase signal U_Ω that can be used for switching off the load(s). The main function of the variable inductance is to ensure that the amplitude of U_Ω is virtually independent of the load current. To achieve this, the control centre sets the required inductance with the aid of a servo-motor.

Modulation type

The modulation voltage should be not smaller than $0.01U_\approx$ to allow a suitable noise margin for the receiver, and not greater than about $0.05U_\approx$ to prevent it disturbing the operation of certain loads. In analogy with ordinary amplitude modulation, the modulation depth, or relative amplitude of U_Ω with respect to $U_\approx$, is expressed as

$$m = \frac{U_{\Omega(max)}}{U_{\approx(max)}}$$

The modulation method used in the above control system is less simple to qualify than would be expected. It could be called a special form of *amplitude modulation*, since the modulation voltage is unipolar, causing amplitude variation of either the positive or negative half cycles of the carrier voltage, but not both simultaneously. The system could also be considered as based on *phase modulation*, because it involves the sum of two amplitude-modulated voltages of equal frequency but opposite phase. *Waveform modulation* may be a suitable qualification because the modulation voltage, U_Ω, effectively changes the waveform of the sinusoidal carrier voltage.

Readers are advised that Mains Signalling in the UK is subject to the provisions of British Standards BS6839. Further information on the subject may be obtained from BIMSA (BEAMA Interactive and Mains Systems Association), Leicester House, 8 Leicester Street, LONDON WC2H 7BN, telephone 01-437 0678.

Mathematical and experimental analyses of the spectrum of the modulated voltage supplied by the proposed system show that it consists mainly of even harmonics, among which the second, $2f$, dominates. In this regard, the change of the carrier waveform caused by the modulation could be qualified as *distortion*, and can be expressed as a distortion factor, k. It can be shown that this is roughly equal to the previously mentioned modulation depth:

$$k = \frac{\sqrt{U_2^2 +}}{U_1} \approx \frac{U_\Omega}{U_\approx} = m$$

But this is not a pure type of modulation. In order to improve the noise resistance of the receiver, the maximum positive and negative excursions of the carrier voltage have to be decreased in an alternative fashion, which has the basic elements of phase modulation.

Being able to bring about a difference ΔU_Ω between the positive and negative maximum excursions of $U_\approx$ by means

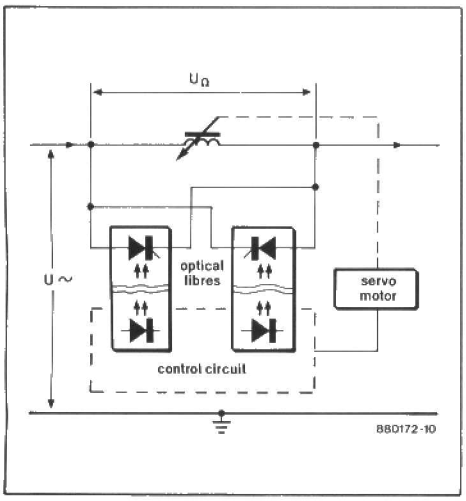


Fig. 1. Series connection of a modulator in a high-voltage line.

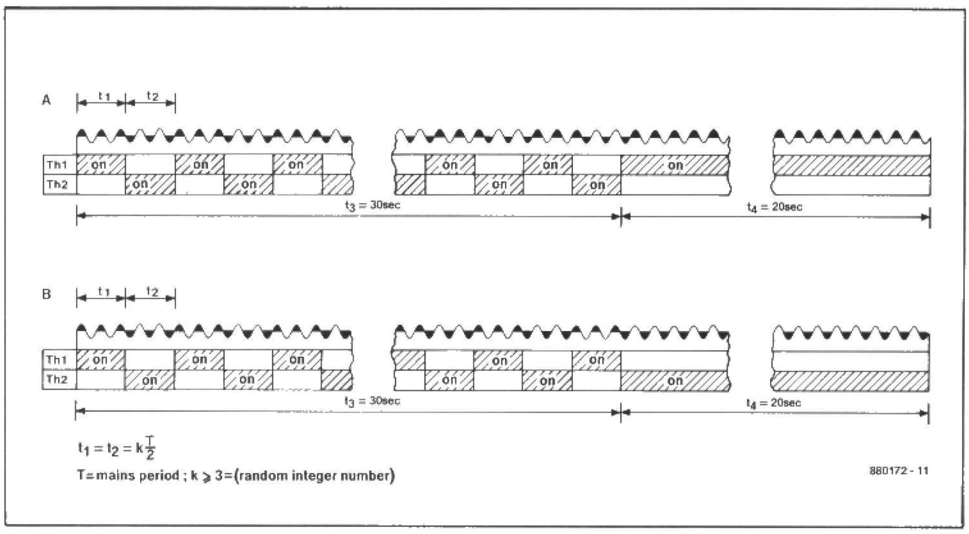


Fig. 2. Thyristor timing diagrams: load on (2a) and load off (2b).

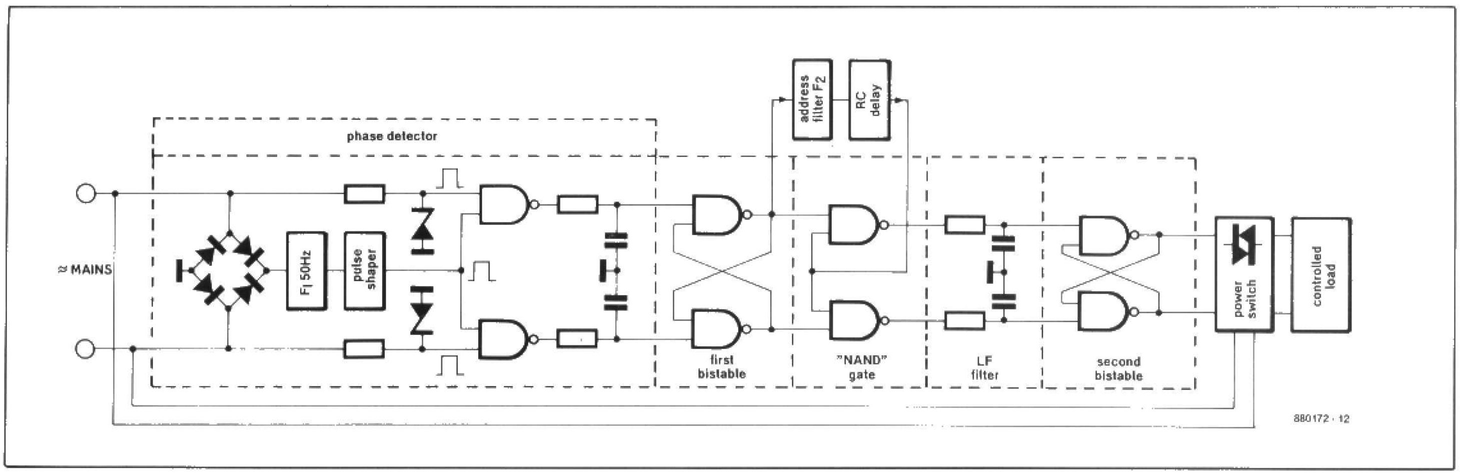


Fig 3. Block diagram of the selective receiver.

of a modulator in a high-voltage line is essentally the same as injecting a signal of amplitude 0.5ΔU₀ and of frequency $2f$ — the frequency of the second harmonic.

Normally, odd-numbered harmonics with $k=0.03$-0.04 are permanently present in many mains networks, while even-numbered harmonics appear only from time to time when large loads are switched on or off. Their total duration is relatively short at about 5% of the 'quiet' periods.

Encoding system

Encoding of the modulation signal is essential in view of the relatively high noise level on most mains networks. The timing diagrams of Fig. 2a and 2b show how the control centre sends trigger pulses to the thyristors to switch a load on and off respectively. The load, or group of loads, controlled is selected by assigning a corresponding value to k.

The block diagram of the receiver is given in Fig. 3, and the practical circuit in Fig. 4. A full-wave rectifier drives an active filter. In the absence of a modulation voltage, all maximum excursions of the rectified voltage are of equal amplitude, and there is no voltage at the output of the filter. When the mains network is modulated, the filter supplies a sinusoidal output voltage, whose phase shifts 180° when the thyristors in the transmitter change state (on/off control). A phase detector compares the phase of the filter output signal with that of the mains voltage. One of its outputs supplies the demodulated signal, U_Ω. Bistables, a load address decoder/filter and delay networks are then used to achieve reliable control of the power switch for the load. The filter is laid out in accordance with the load selection frequency:

$$f=2/(k\ T)$$

The possible number of load selection frequencies is more than ten, but practical needs normally seldom exceed about five.

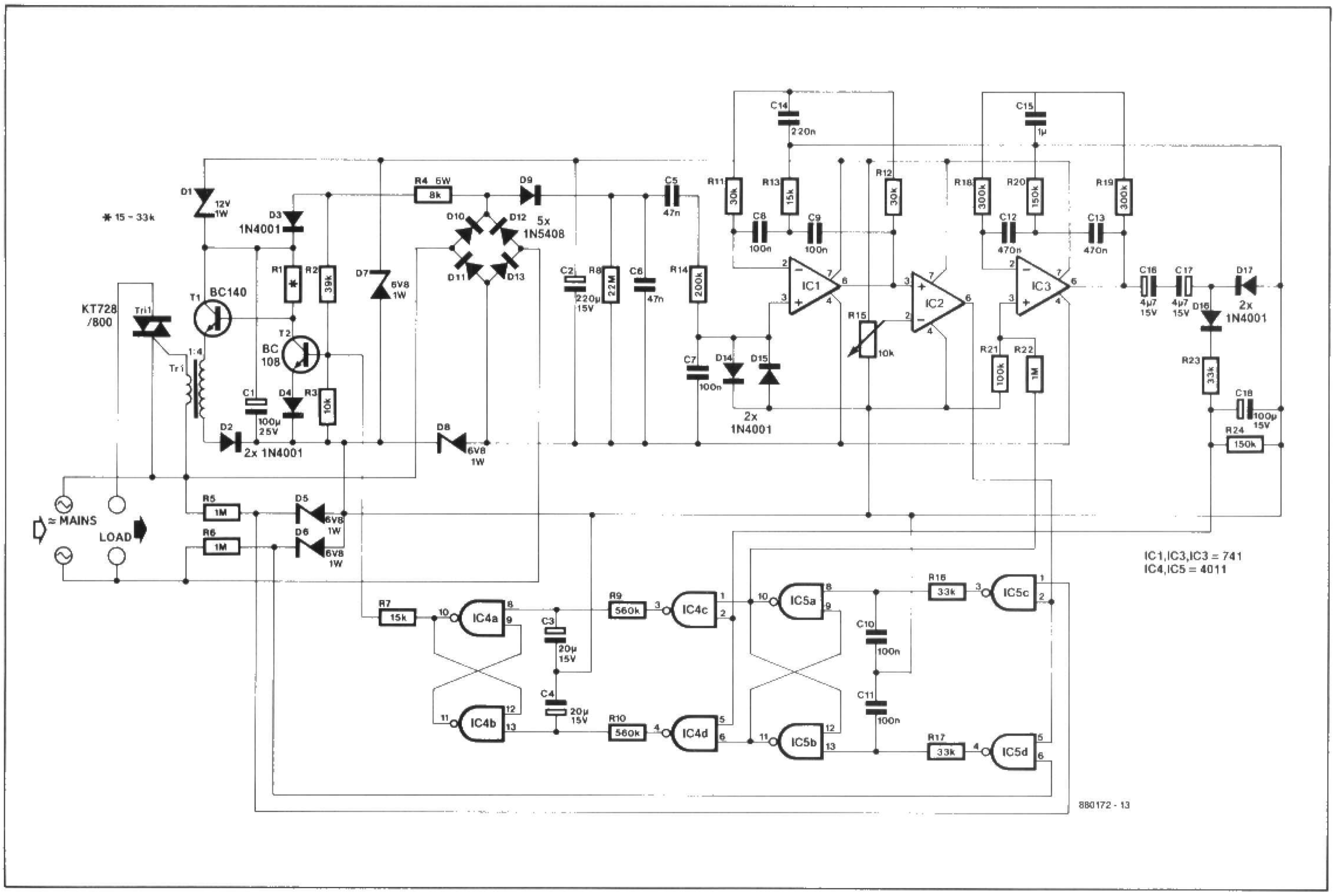


Fig. 4. Circuit diagram of the receiver.

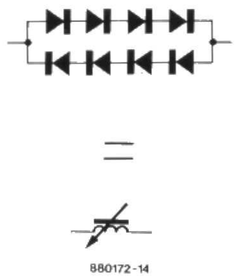


Fig. 5. Eight high-voltage diodes as a replacement for the variable inductor in the transmitter.

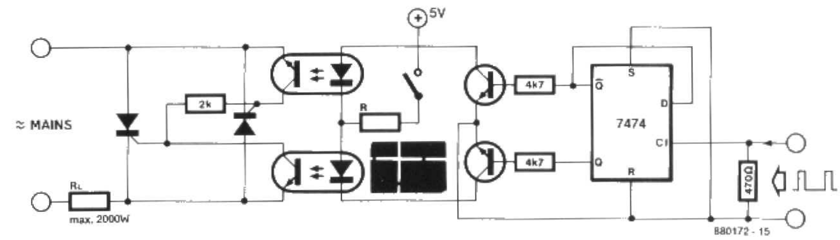


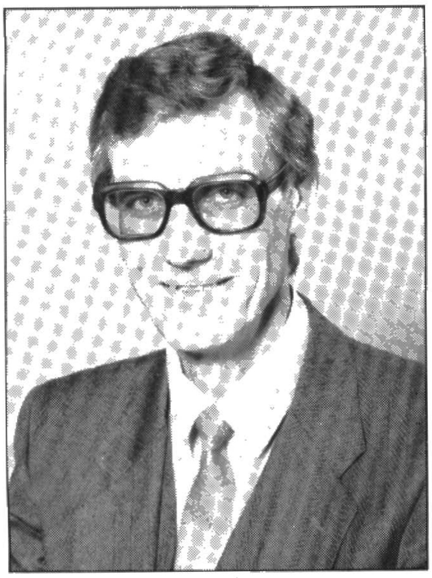
Fig. 6. Basic layout of a parallel modulator.

The cost of the transmitter and receiver compares favourably with existing units based on so-called ripple control of the mains voltage.

Finally, Fig. 5 shows a suitable replacement for the variable inductor in the transmitter. It should be noted that the diodes have to be capable of handling the total current demand of the load or group of loads. The block diagram of an alternative, parallel, modulator is shown in Fig. 6.

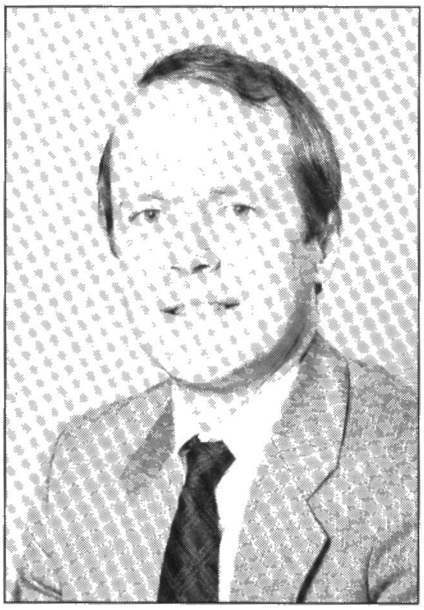
PEOPLE

Samuel Ruben, who died recently at the age of 88, was the inventor of the dry-plate rectifier and the dry-electrolytic capacitor. In association with P.R. Mallory, the founder of Duracell, he also developed the first practical design for an alkaline cell. This cell was ready just in time for World War II, during which its consistent voltage and its resistance to deterioration under adverse conditions made it the preferred power source for battery-powered military equipment.



Cliff Wyatt

Cliff Wyatt is the Business Manager of the OEM Products and Service Group recently established by Base Ten Systems of Farnborough. Richard Nussey is the Product Manager of the new group and Chris van Koutrik has been appointed Sales Engineer.



Richard Nussey

In addition to providing wide-ranging manufacturing services for the electronics industry, the group will be involved in the introduction of new high technology products and will seek joint business opportunities with other organizations for this purpose.

Mr M.K. Williams has been appointed Research Associate for Dataquest's European Semiconductor Industry Service. At the same time, Mr W. Turnbull has been appointed Industry Analyst for the organization's Western European Printer Industry Service.

Bob Hawkins has joined STC Instrument Services as a field sales executive.

Andrei Vladimirescu, internationally recognized as an expert on the subject of circuit simulation, has joined Analog Design Tools as director of simulation technology.

Ray Rees has been appointed director of LSI Logic Export Ltd, part of LSI Logic Europe PLC, manufacturers of CMOS ASICs and market leader in CMOS gate arrays. LSI Logic has also announced the appointment of **Simon Calder** as Product Marketing Manager.

Roy Home has been appointed Managing Director of Parker-Digiplan, a division of the Parker Hannifin Corporation and Europe's leading manufacturer of servo drives, motors, and control systems.

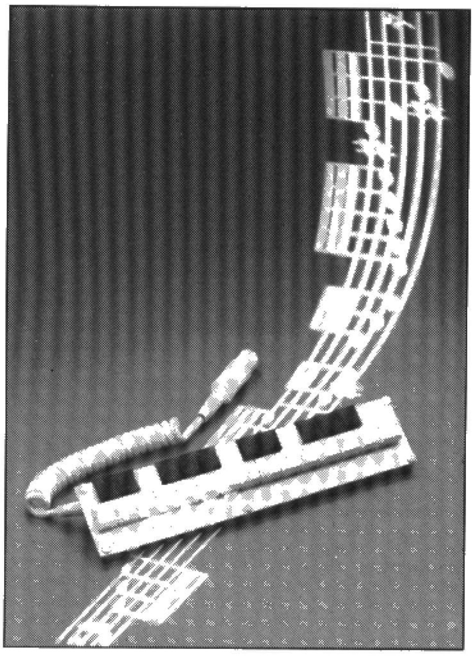
Liz Hindley has joined Alpha Electronics as internal Sales Manager.

PORTABLE MIDI KEYBOARD

A recently introduced integrated citcuit makes a dream of many electrophonics enthusiasts come true: to build one's own MIDI keyboard around a handful of electronic components.
The portability of the keyboard described makes it ideal for 'first-aid' testing of MIDI equipment. Moreover, in conjunction with a microcomputer, it can be used for practising, composing and editing musical pieces in places where a full-size keyboard is cumbersome to use.

The Type E510 is a recently introduced integrated circuit that reduces the complexity of a MIDI keyboard to the extent that home construction of such a unit is at last within reach. Until recently, building one's own MIDI keyboard was way of out reach of the average electrophonics enthusiast because of cost and complexity. At that time, even the simplest of do-it-yourself MIDI keyboard required building blocks such as a processor, random-access memory, read-only memory, high-precision mechanical parts to ensure good dynamic key response (velocity), a musical keyboard, and a data entry keyboard, to mention but a few.

The E510 can be used with a musical keyboard of ten octaves (128 keys) whose keys are suitable for providing the velocity information. The only auxiliary components needed are an EPROM loaded with transposition data, two binary decoders, and, of course, key contacts.
The benefits of a portable keyboard are obvious: quick testing of MIDI instrument arrangements, practising and composing (parts of) musical pieces, participating in workshops, and trying out chords or tone combinations in situations where a full-size keyboard simply takes up too much space. The miniature keyboard is also very useful for simulating a temporarily absent instrument or full-size keyboard for editing sequences loaded in a sequencer, sounds in an expander, or scores in a computer system.
Apart from its function as a versatile accessory in the musical education field, the keyboard will also prove useful for experienced musicians whose principal instrument is, for example, the saxophone, the guitar or percussion — in any case, not the piano. Even if the mini keyboard serves as a mere gadget, it still deserves its very own place among far more complex MIDI equipment.



MIDI KEYBOARD

- Overall size geared to portable applications.
- Electronic circuit complies with MIDI standard (incl. velocity).
- Miniature keys and control circuit on compact double-sided PCB.
- Range: 2 octaves and 1 note (25 keys); from C to C.
- Switch-controlled transpose function over ±1 octave.
- Switch-controlled MIDI channel selection (channel 1 or 2).
- Simple to power from mains adaptor with DC output.
- Low chip-count.

MIDI keyboard: principle of operation

The task of the MIDI keyboard is to detect the individual states of the keys to enable polyphonic playing. This means that a number of notes can simultaneously appear or disappear, notes can last when others stop, and notes can appear before others have dissappeared. It is the aspect of polyphony that makes a musical keyboard functionally completely different from, say, a computer or data entry keyboard.
The 'key state' means that it is either released (the corresponding contact is in the non-actuated, or rest position), pressed (the corresponding contact is actuated), or in between these extremes. The time that lapses between the instant when a key is no longer in the rest position, and the instant it reaches the work position, is translated into a VELOCITY value. Evidently, the velocity at which the key is pressed is proportional to the

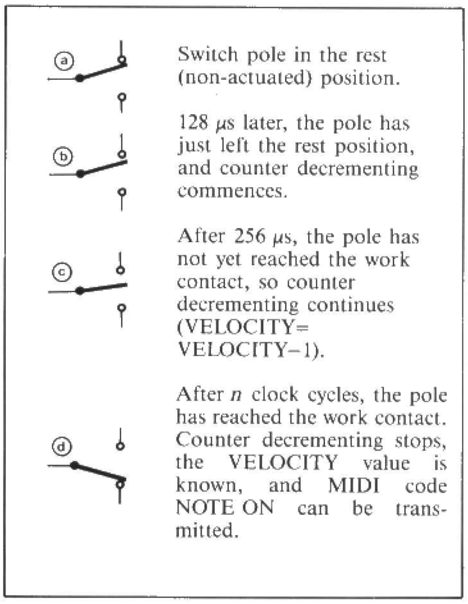


Fig. 1. The main functions of the electronics in the MIDI keyboard are to analyse the position of the keys, and to measure the time that lapses between the opening and closing of the contacts, for both directions of travel of the switch pole. Although in principle available on the small MIDI keyboard discussed here, the latter function is, unfortunately, of no use because the relevant switches are of a type whose pole travel is virtually instantaneous rather than continuous.

intensity with which the player strikes it. The softer the key is struck, the more time will lapse before the pole of the key has travelled from the rest contact to the work contact. This time is measured by counting down from 127 to 1 (see Fig. 1); the smaller the final count, the softer the key-touch.

When it is detected that a key is no longer in the non-actuated position, nothing happens on the MIDI output of the keyboard. Counting down, however, commences or continues. Code NOTE ON is not transmitted until the pole reaches the work contact. If the minimum VELOCITY value is reached by decrementing before the pole reaches the work contact, it is assigned the lowest value, 1. Basically the same happens when a key pole leaves the work position to return to the rest position.

The scanning of a MIDI keyboard thus entails the fastest possible analysis of the state of each key. In practice, this is achieved by an electronic circuit that works in combination with mechanical change-over (toggle) switches to derive key on/off and velocity information.

MIDI keyboard controller Type E510

Figure 2 shows the internal structure and pinning of the programmed MIDI keyboard controller Type E510. The power supply is conventionally connected to pins 8 and 16. The keyboard scanning signal and the timing of the serial MIDI data are derived from an on-chip clock oscillator that operates with an external 4 MHz quartz crystal connected to pins 14 and 15 (pin 15 may be used for applying an external clock signal). The data rate at the MIDI output may be doubled by fitting an 8 MHz crystal. Pin 13 should always be connected to the positive supply line.

Chip outputs A0 to A6 allow the controller to scan up to $2^7=128$ addresses (=keys). The MIDI data is available at output SO (pin 9). This output can be used in two ways: it can be made TTL-compatible by fitting a pull-up resistor, or it can function as a current-source by fitting a series resistor. The latter option is used here to give a MIDI-compatible current loop output.

Input BE is connected to the 'bused' rest contacts of the switches. Similarly, input BS is connected to the work contacts of the switches.

The pole of a switch addressed by the E510 is made logic low. During scanning, when the pole is at the rest position, the level of line BE is logic low instead of logic high (normal state due to pull-up). When the key pole has reached the work contact, BS goes logic low. Neither BS nor BE is low when the pole is anywhere between the rest and the

THE MIDI STANDARD: A BRIEF RECAPITULATION

The acronym MIDI stands for *Musical Instrument Digital Interface*. This standard has been designed to allow digitally-controlled musical instruments to communicate in a system (note that digital control often implies the use of a microprocessor or microcontroller, although this is, of course, not always necessary). The MIDI interface is basically a serial data link, based on a current loop. The data format is: 1 start bit, 8 data bits, and 1 stop bit. The data speed, 31.25 kilobits per second, is high relative to that used for many types of computer peripherals, but may still be too slow for real-time operations of a complexity beyond that of the most rudimentary types. The bulk of MIDI data is formed by the notes (*events*), played on a keyboard, or transmitted by an instrument. This recapitulation covers only MIDI events such as the NOTE ON and NOTE OFF messages.

Of the three bytes in a 'NOTE ON' message, the second one carries the note value. With the MSB (most significant bit) set to 0 to indicate that the byte is a data type, this leaves only seven bits to carry the note value. This gives a range of 2^7 values, and these are assigned numbers from 1 to 127. The value of 60 is equivalent to the middle C. The interval between any two adjacent numbers is a semitone, so that a total compass of about ten and a half octaves is available.

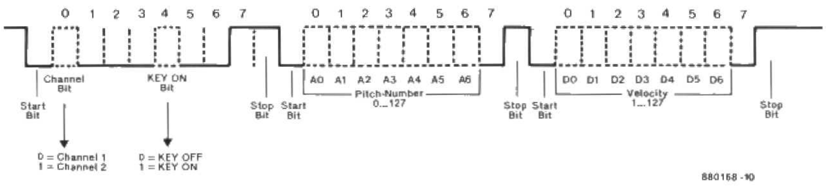
MIDI VALUES: NOTES											
0	12	24	36	48	60	72	84	96	108	120	127
		C1	C2	C3	C4	C5	C6	C7	C8		
		range of piano									

In addition to PITCH, the MIDI standard uses parameters NOTE ON and NOTE OFF (or KEY ON and KEY OFF). The first corresponds to the actuation of a key (or, in more general terms, to the start of the note), the second to the release of the key (end of the note). In reality, the relation between the duration of the note and the transmission of data NOTE ON and NOTE OFF is much more complex. Although the start of a note usually coincides with the transmission of code NOTE ON, the complementary code, NOTE OFF, rarely marks the end of the note — usually, by the time NOTE OFF is transmitted, the note is already ended (in the case of a percussion sound without sustain), or it still sounds (long sustain).

The third byte in the 'NOTE ON' message provides keyboard velocity information. Ranged in values from 1 to 127, the velocity is normally used to control the loudness of the notes (0='key off'; 1=pianissimissimo — *ppp*; 127=fortissimissimo — *fff*). It should be borne in mind, however, that there is no specified relationship between the velocity value and the loudness. If a MIDI instrument is not designed to handle velocity information, it adopts a default value (usually 64).

MIDI VALUES: VELOCITY								
0	1			64				127
OFF	ppp	pp	p	mp	mf	f	ff	fff

Since a single MIDI interface can be used for connecting several MIDI devices, provision has been made to identify data to ensure it is correctly routed in multi-instrument set-ups. This data marking allows individual addressing of any instrument connected to a single MIDI interface. The MIDI standard specifies up to 16 channels, numbered 0 through 15 (sometimes 1 through 16), which means that any one of up to 16 instruments can be controlled independently and individually. In the case of the NOTE ON and NOTE OFF information, the channel number forms part of the ON or OFF code.



The above diagram shows a MIDI message sent by a keyboard when a a key is actuated. The start bit is followed by an 8-bit word, in which the first 4 bits (0 through 3; least significant nibble) indicate the channel number (the keyboard described in this article can drive only two channels). The last bit, (number 7; most significant bit) is logic high to indicate that the byte sent represents *status information*, i.e., it is not, strictly speaking, a *data* word. The logic level of bit 4 provides the KEY ON/OFF (NOTE ON/OFF) information: 0=OFF; 1=ON.

The six bits that indicate the key number follow the start bit of the second byte. Bit 7 of a databyte is always logic low. The six bits of the third byte (second databyte) hold the velocity information. Bit 7 is logic low to mark that the byte it forms part of is still a databyte. In the present case, the MIDI message is terminated with the stop bit of the third byte.

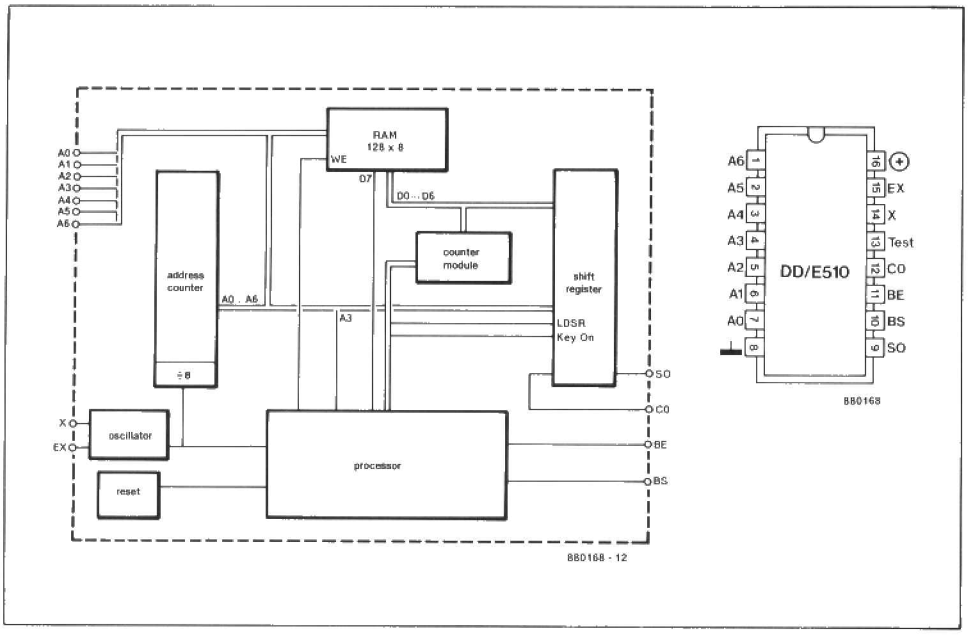


Fig. 2. Internal structure and pinning of the polyphonic MIDI keyboard controller Type E510. This chip supports the use of a 128-key keyboard with up to 10 octaves, and transmits MIDI values for VELOCITY, NOTE ON and NOTE OFF.

Table 1.

key	BE	BS	function
1	x	x	not analyzed
0	0	1	pole at rest contact
0	1	0	pole at work contact
0	1	1	pole travelling
0	0	0	impossible

x = irrelevant

work contact. The above arrangement is summarized in Table 1.

The logic level at chip input C0 (pin 12) determines the current MIDI channel: C0=0=channel 0; C0=1=channel 1.

Circuit description

The crucial components in the circuit diagram of Fig. 3 are controller IC_1 (E510) and decoders/demultiplexers IC_3 and IC_4. EPROM IC_2 has the auxiliary function of code converter.

The operation of the circuit is best understood if IC_2 is initially ignored. It is assumed, therefore, that the address outputs of IC_1 drive IC_3 and IC_4 direct. On its outputs A0 to A6, the E510 counts from 0 to 127. Each time the counter is incremented, another output on IC_3, and then IC_4, goes low. This cyclic counting up forms the scanning of the keyboard. Each time the E510 pulls one of its address lines logic low, it reads back the logic levels of lines BS and BE to determine the current state of the addressed key. This state is combined with that read during a previous scan (i.e., 128 μs earlier at f_{XTAL}=4 MHz). The

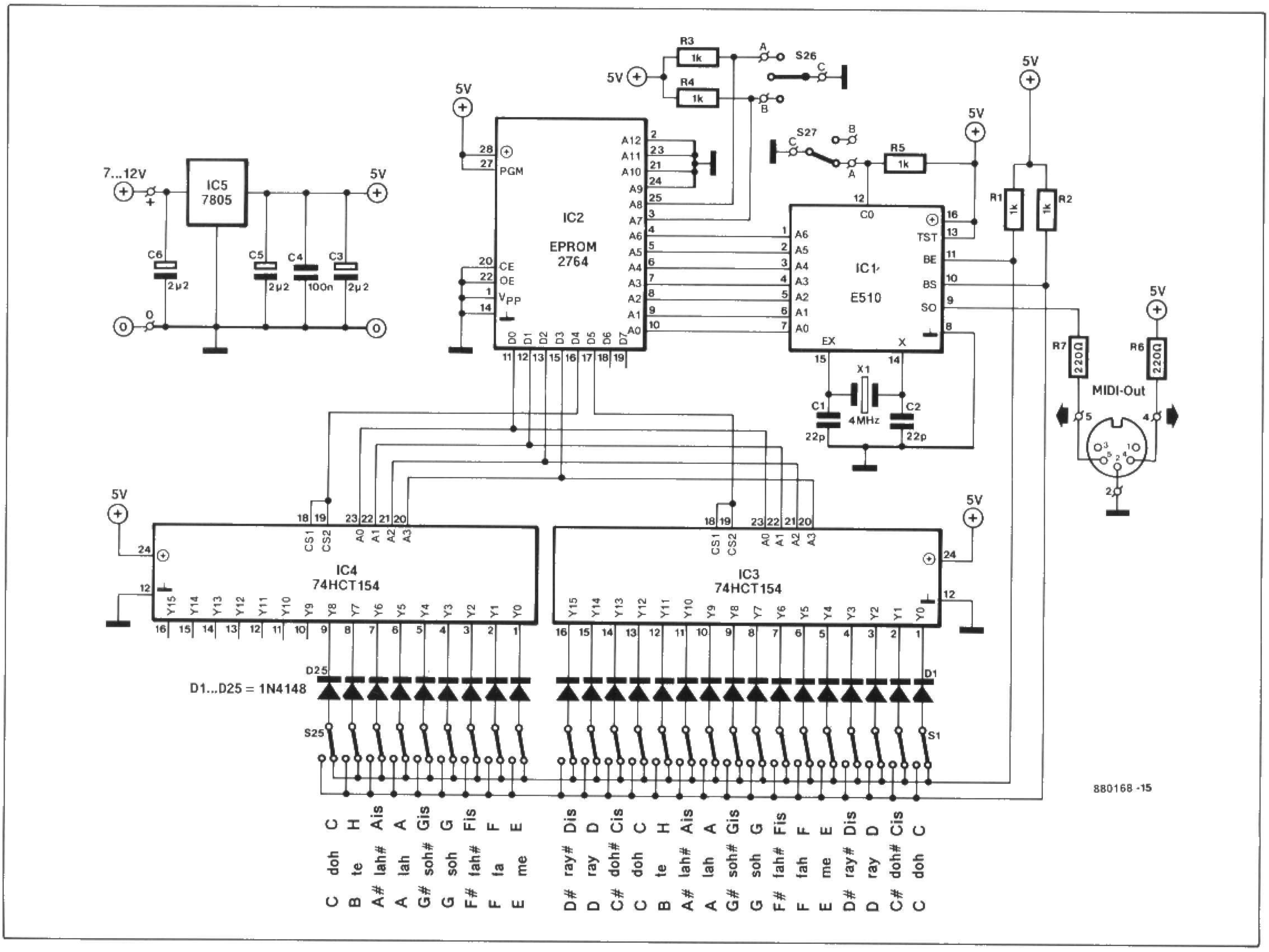


Fig. 3. Circuit diagram of the small MIDI keyboard.

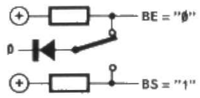
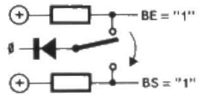
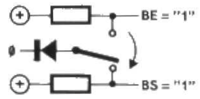
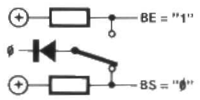
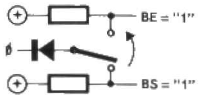
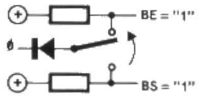
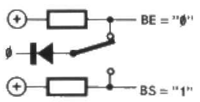
result of the combination is deduced as shown in Table 2.
That the keyboard described here has 25 instead of the maximum number of 128 matters very little as far as the electronics are concerned, since BE and BS simply remain logic high simultaneously for the 103 non-existing keys, and state BE=BS=1 is effectively ignored by the E510. Although the contact travel time of the Digitast keys used in the MIDI keyboard can be measured with some precision, it will be found that this is largely constant, i.e., hardly subject to applied force. This is because Digitast keys have tactile feedback (they produce a click when pressed). The upshot of it is that the VELOCITY value transmitted by the *standard* version of the keyboard is of no practical use.

As already noted, EPROM IC_2 functions as a code converter in the present circuit. The E510 counts cyclically from 0 to 127. In the absence of the EPROM, the two octaves of the keyboard would be comprised in the lowest range of the scale covered by the PITCH parameter, i.e., between note 0 and 24. Also, double addressing of the decoders in the circuit would cause a single key to provide several, different, MIDI codes simultaneously. The task of the EPROM is, therefore, to ignore the lowest of the address codes, and to activate the two decoders (74HCT154) *only once* when the counting has reached a value that corresponds to audible notes in the middle of the useful range.
The second duty of the EPROM is to switch between two address ranges, which results in the transpose function. This is effectively done with the aid of a toggle switch with a centre contact, S_{26}, that determines the logic level on EPROM address inputs A7 and A8. The EPROM converts the addresses supplied by the E510 by adding or subtracting the equivalent of one octave. For example, when the address of note 60 is applied, the EPROM converts this to an address that corresponds to note 72, one octave higher. The contents of the EPROM are listed in Table 3. A Type 2764 is used here because this is currently the least expensive EPROM.

Split programming extension

Switch S_{27} determines the channel selection by controlling the logic level aplied to input C0 of the E510.
Instead of manually giving a channel selection command, it is also possible to do this via the keyboard by splitting this into zones. Figure 4 shows the circuit diagram of the optional extension to achieve this. Notes played to the left or the right of the split go to MIDI channel 1 or 2 respectively. The split is defined by pressing the PROGRAM switch together with the desired key on the

Table 2.

Previous state	New state	Event	Key state
rest BE=**0**; BS=1	rest BE=**0**; BS=1	none	
rest BE=**0**; BS=1	intermediary BE=1; BS=1	start count	
intermediary BE=1; BS=1	intermediary BE=1; BS=1	continue count (to 1)	
intermediary BE=1; BS=1	work BE=1; BS=**0**	end of count message MIDI NOTE ON	
work BE=1; BS=**0**	intermediary BE=1; BS=1	start count	
intermediary BE=1; BS=1	intermediary BE=1; BS=1	continue count (to 1)	
intermediary BE=1; BS=1	rest BE=**0**; BS=1	end of count message MIDI NOTE OFF CO = MIDI CHANNEL A6. . .A0 = PITCH count = VELOCITY	

0 = active
count = decrement counter

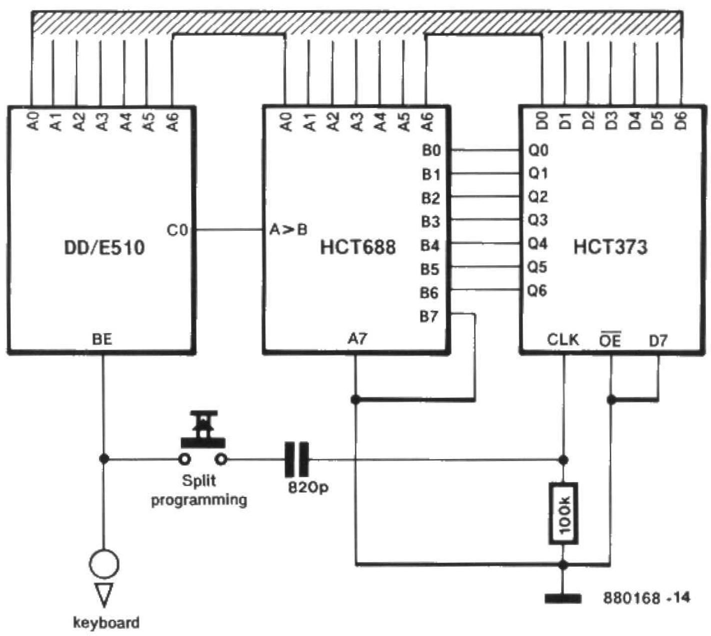


Fig. 4. Optional add-on circuit to achieve programmable split zoning.

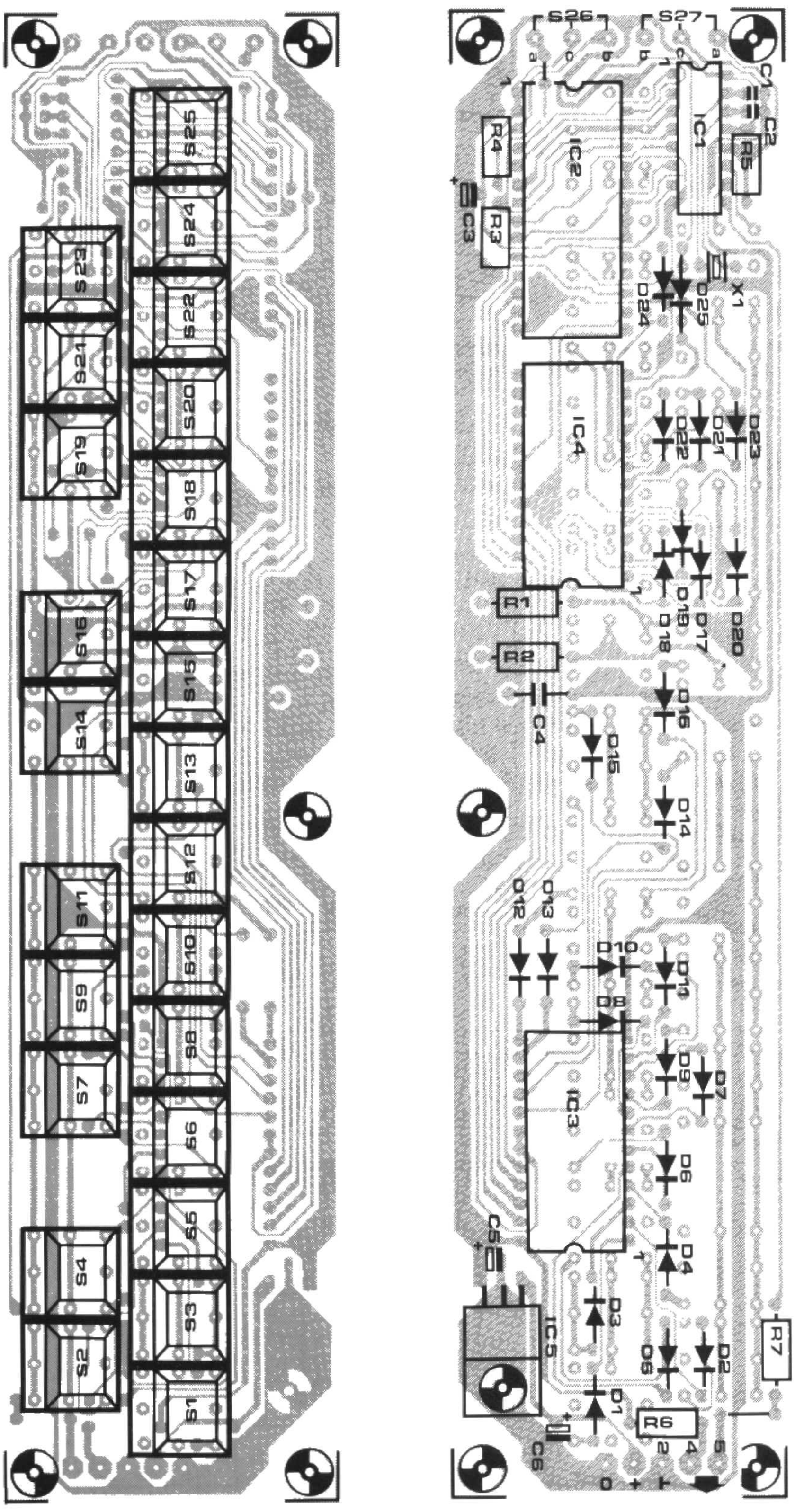


Fig. 5. Component mounting plan of the printed circuit board for the MIDI keyboard.

Parts list

Resistors (±5%):
R1 . . . R5 incl. = 1K0
R6;R7 = 220R

Capacitors:
C1;C2 = 22p
C3;C5;C6 = 2μ2; 25 V; tantalum
C4 = 100n

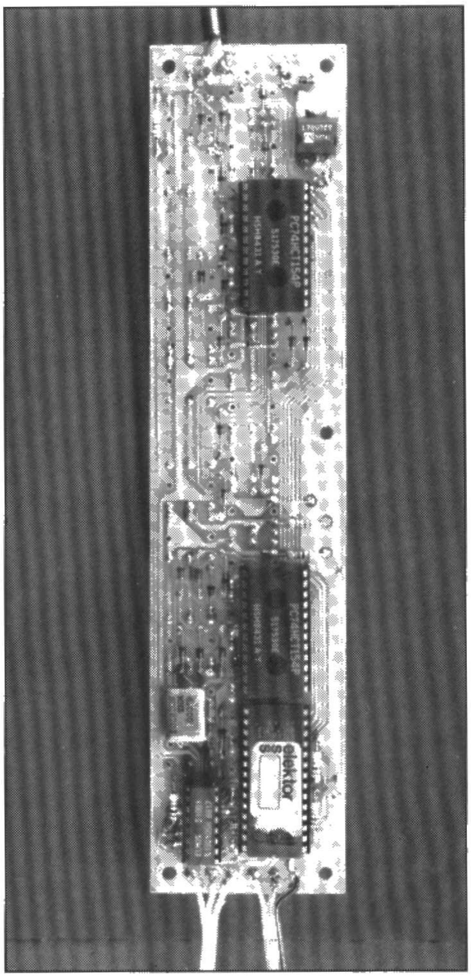
Semiconductors:
D1 . . . D25 incl. = 1N4148
IC1 = E510 +
IC2 = 2764 (ESS567; see Readers Services page)
IC3;IC4 = 74HCT154
IC5 = 7805

Miscellaneous:
S1 . . . S25 incl. = miniature Digitast toggle (SPDT) key.
S26 = miniature toggle (SPDT) switch with centre position.
S27 = miniature SPDT switch.
X1 = quartz crystal 4.00 MHz
PCB Type 880168 (see Readers Services page).

keyboard. The corresponding key number is then latched into the 74HCT373 octal bistable. Byte comparator 74HCT688 drives input C0 of the E510 logic low when the current key code is greater than that of the split, which is read from the latch. The programmable split option is not supported on the printed circuit board for the MIDI keyboard, since this was desired to remain as small as possible.

Construction

The following constructional description is slightly more elaborate than usual to enable anyone, even those with only limited experience in the electronics field, to build the keyboard successfully.



Prototype of the MIDI keyboard

Table 3 TRANSPOSITION DATA

Addresses applied to transposition EPROM:

S26		count from 0 to 128						
A8	A7	A6	A5	A4	A3	A2	A1	A0
0	1	0	1	0	0	1	0	0
1	0	0	1	1	1	1	0	0
1	1	0	1	1	0	0	0	0

note	C	S26
n° 36	2	−1 oct.
n° 60	4	+1 oct.
n° 48	3	normal

Output data supplied by transposition EPROM:

D7	D6	D5	D4	D3	D2	D1	D0	hex	
NC	NC	0	1	0	0	0	0	10	keys 0 to 15
NC	NC	0	1	1	1	1	1		74HCT154/IC3
NC	NC	1	0	0	0	0	0		keys 16 to 25
NC	NC	1	0	1	0	0	0	28	74HCT154/IC4

Table 4. EPROM CONTENTS

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
00A					10	11	12	13	14	15	16	17	18	19	1A	1B
00B	1C	1D	1E	1F	20	21	22	23	24	25	26	27	28			
...																
013													10	11	12	13
014	14	15	16	17	18	19	1A	1B	1C	1D	1E	1F	20	21	22	23
015	24	25	26	27	28											
...																
01B	10	11	12	13	14	15	16	17	18	19	1A	1B	1C	1D	1E	1F
01C	20	21	22	23	24	25	26	27	28							

Addresses not given are left blank (FF)

Construction is not difficult, but requires great care and precision because components are fitted at both sides of the printed circuit board, which is quite densely populated.

The first thing to note is that the components, with the exception of the keys, are fitted **at the track side of the board**. The holes in the board are intended for the wires and the keys. All other component terminals are cut to a suitable length, preformed, and soldered direct to the relevant copper islands.

Commence construction at the track side by fitting the two wire links: one between R_6 and R_7, and the other, a very short one, close to solder terminal **a** of S_{26} (in both cases, use insulated wire to prevent a short-circuit with tracks running below). Next, mount the 25 Digitast keys at the reverse side of the board (note that a number of keys can not be soldered any more once the integrated circuits have been fitted). Study the orientation of each and every diode before fitting it!

Mount the solder terminals for the wires to the board (MIDI output and power supply), and then those for S_{26} and S_{27}. Depending on personal preference, these switches are either mounted direct on to the board (to the right of the Digitast keys), or on the front panel of the enclosure that houses the MIDI keyboard. Cut the terminals of voltage regulator IC_5 to a length of about 3 mm from the enclosure, bend them over, and place their ends on the spots provided. Insert an insulating mica washer between the metal tab of the regulator and the PCB surface. Secure the regulator with a short M3 bolt and nut.

Take great care to avoid short-circuits between component terminals and nearby tracks. Make sure that the leads of the quartz crystal are left long enough to enable the metal enclosure to be bent towards the PCB without touching the solder joints below. Bend D_{25} slightly away from the crystal enclosure.

There is no objection to confident and experienced constructors soldering the integrated circuits direct on to the board. If you are hesitant about doing this, however, use low-profile IC sockets. Since the E510 may have to be removed for use later in a full-size touch-sensitive keyboard (see below), it is recommended in all cases to fit this IC in a socket.

Finally, be sure to use good-quality strain reliefs for the MIDI output and supply cables.

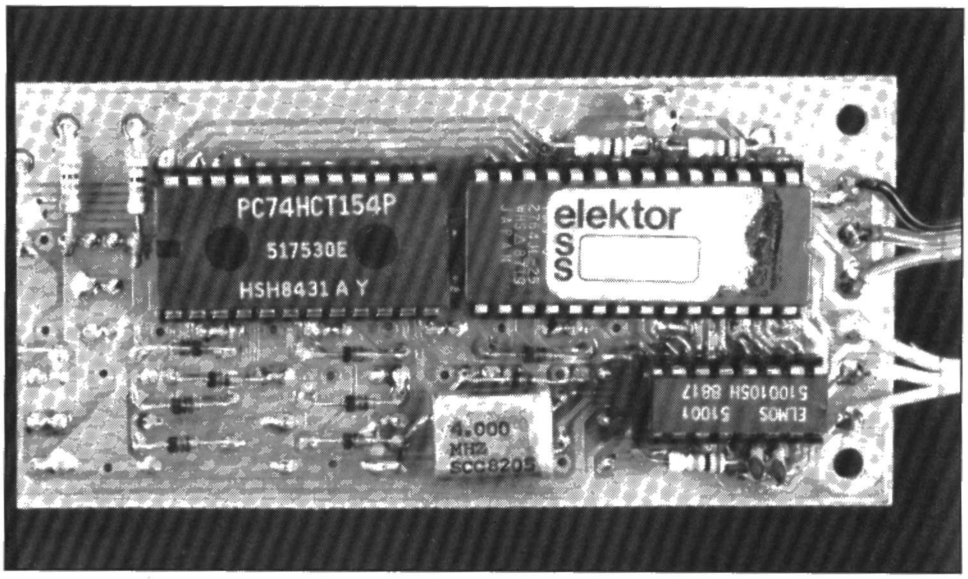
From mini to full-size

The electronics in the MIDI keyboard is suitable for connecting to a 'real' keyboard, i.e., one of standard size and having change-over key contacts of a quality that ensures equal VELOCITY values over the full keyboard range.

The function of a sustain pedal can be created by inserting a push-to-break button in the pulled-up BE line to the E510. This switch, when pressed, prevents the E510 from detecting that actuated keys have returned to their rest position, in which case BE is logic low.

For further reading:

Fantasia on a MIDI theme. *Elektor Electronics* November 1985.
MIDI expander from Böhm. Elektor Electronics March 1986.
MIDI keyboard from Böhm. Elektor Electronics June 1986.
MIDI signal redistribution. *Elektor Electronics* May 1987.
MIDI split control. *Elektor Electronics* March 1987.
MIDI code generator. *Elektor Electronics* April 1988.



OPTOELECTRONICS

by K. Roberts, BA

Optoelectronics is one of the fastest growing branches of electronics and British research and development is leading the world in many of its facets. Although this technical excellence is not (yet) matched in the commercial sector, companies operating in the opto-electronics field are increasingly exploring export markets and seeking international collaboration. Already, many export more than half their production and some export nearly all of it.

Optoelectronics may be defined as the technology that makes use of the interaction between photons (small packets of light energy) and electrons. The study and science of this interaction is called photoelectronics, often, particularly in the USA, contracted to photonics.

Broadly speaking, optoelectronic products may be categorized into sensors (responders to light), emitters (of light), and users (of light), which are often a combination of the first two.

Sensors comprise, among others, photocells, also called light-dependent resistors (LDR); solar cells; photodiodes; and phototransistors.

Emitters comprise ordinary light bulbs; light-emitting diodes (LED); gas discharge tubes; lasers; electroluminescent displays; and cathode ray tubes.

Users comprise optocouplers, sometimes called opto-isolators; infra-red alarm and remote control systems; security installations; and metrological devices.

Sensors

An LDR (photocell) consists of a thin polycrystalline film of cadmium-sulphate sandwiched between two metal contacts. The potential across these contacts is directly proportional to the current flowing through the contacts. The conductivity of the cadmium-sulphate increases greatly (by a factor of about 10^5) when it is subjected to electromagnetic radiation of a wavelength between, roughly, 3×10^{-8} m and 3×10^{-5} m. This results in a photocurrent, superimposed on the small dark current, flowing in an external circuit.

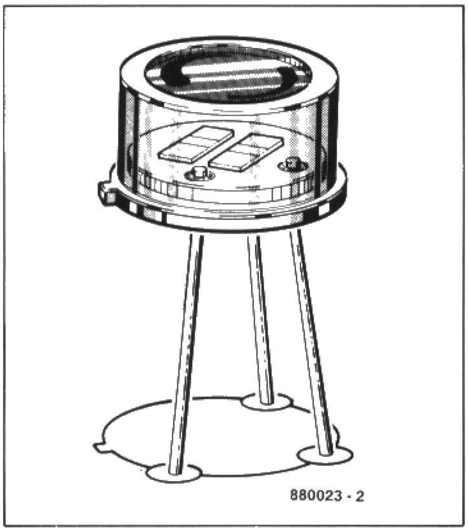


Fig. 1. Typical infra-red sensor.

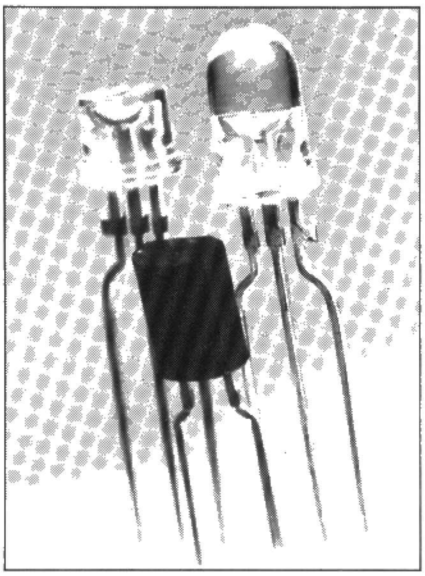


Fig. 2. Some typical phototransistors with in the centre an infra-red photodiode.

A solar cell is a photovoltaic device that converts light directly into electrical energy. It is essentially a *p-n* junction: by far the largest number of solar cells currently manufactured are made from crystalline silicon. Others are made from amorphous silicon, copper sulphide-cadmium sulphide, gallium arsenide, or cadmium-selenium. See Ref. 1.

A photodiode, either of the depletion-layer or of the avalanche type, has its *p-n* junction exposed to external light. The depletion layer type, operated below its break-down voltage, produces excess electron-hole pairs when radiation in the UV–IR region falls on to the junction. The pairs in or near the depletion layer cross the junction and produce a photocurrent. In the avalanche type, operated above its break-down voltage, current multiplication of the electron-hole pairs generated by incident illumination ensues owing to avalanche break-down.

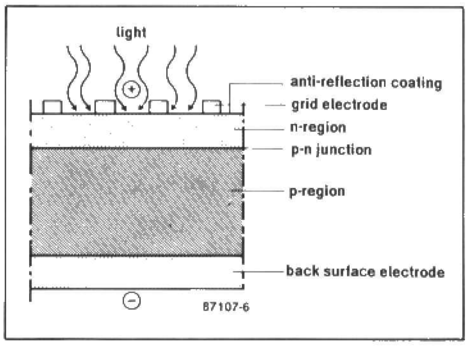


Fig. 3. Basic construction of silicon solar cell.

A phototransistor is a bipolar junction transistor whose junctions are exposed to external light. It is normally operated in the common-emitter configuration. When light in the UV–IR region falls on to the junction, a base current is produced, and the normal current-amplifying action causes a greatly amplified collector current. The phototransistor is, of course, far more sensitive than the photodiode.

Emitters

A light-emitting diode (LED) is a *p-n* junction that emits light as a result of recombination of excess electron-hole pairs. The emission is normally a fairly narrow bandwidth of visible (red, orange, yellow or green) or infra-red light. The colour is a function of the semiconductor material used for the junction. LEDs typically require forward operating voltages of about 2 V and forward currents of 10 to 20 mA.

A gas-discharge, or fluorescent, tube

normally contains a small amount of argon together with a little mercury. It has two electrodes (filaments) that are coated with a mixture of barium and strontium oxides. The resistance between the electrodes is high until the gas is ionized. Gas ionization is usually brought about by the application of a very high voltage (of the order of 1500–2000 V) across the two electrodes.

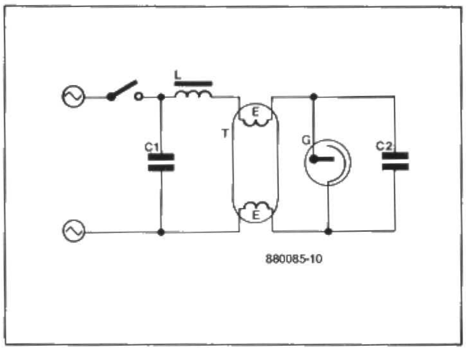


Fig. 4. Circuit of conventional low-pressure fluorescent tube.

The high voltage is normally induced across a starter choke by the sudden disruption of the current through the choke.

The laser was developed by Theodore Maiman in 1960. Light emitted by a laser differs from normal light in two important respects: it is coherent, i.e., all the photons are in phase; and it is of one frequency only.

There are many types of laser: small output He-Ne lasers, primarily intended for use in laboratories; argon-ion lasers for medical applications; carbon-dioxide lasers for industrial uses; dye lasers for use in spectroscopy; high output Nd/YAG lasers for surgical applications excimer lasers for use in chemical analysis and semiconductor processing; and, most common of all, semiconductor, or injection, lasers. The semiconductor laser is of prime importance in modern (fibre optic) communications, optical memories, and compact disc players. See Ref. 2 and 3.

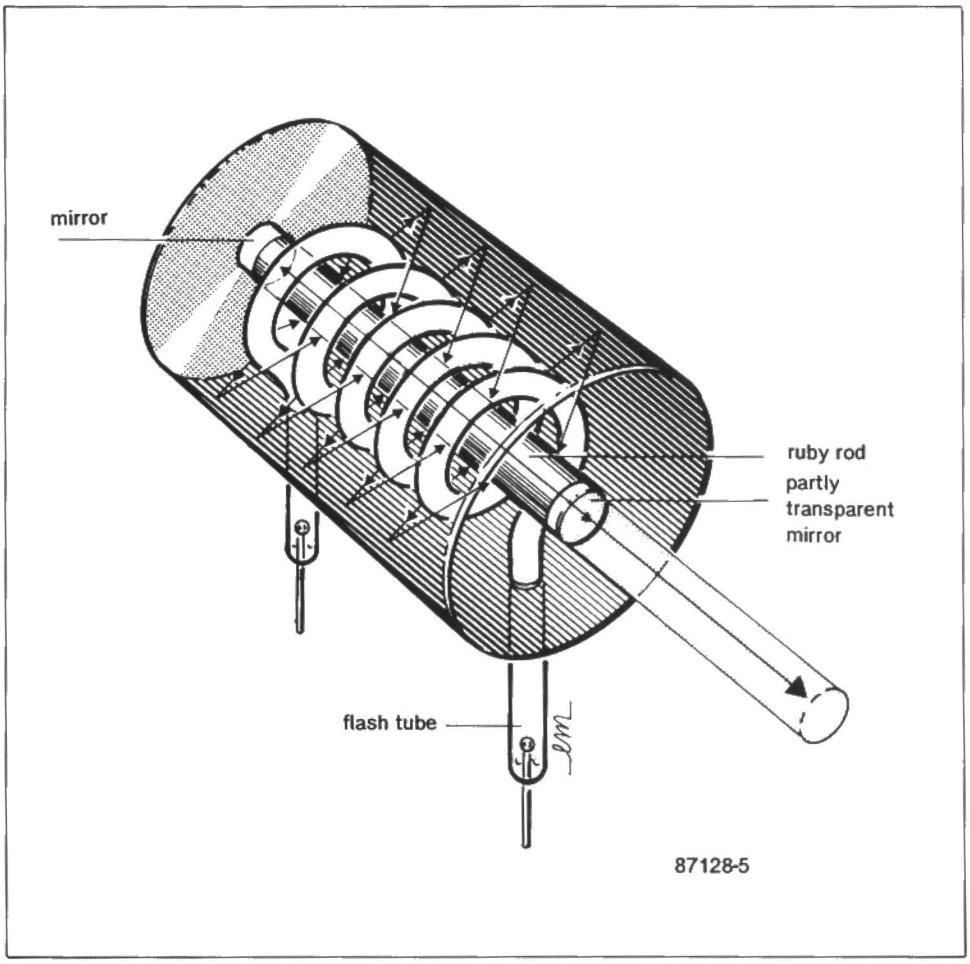


Fig. 5. Artist's impression of the construction of a ruby laser.

Electroluminescent displays make use of the ability of phosphorus to emit light continuously when a voltage is applied to it. The most commonly found application of this phenomenon is in the screen of a cathode ray tube as used in many hundreds of millions of TV sets the world over, not to mention the millions of computer monitors and oscilloscopes. Such a display consists of a sandwich of a luminescent-phophorus layer and two transparent metal films. When an a.c. voltage is applied to the films, the phosphorus glows through the films.

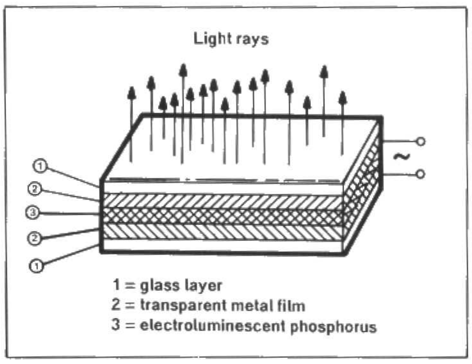


Fig. 6. Basic construction of electroluminescent display.

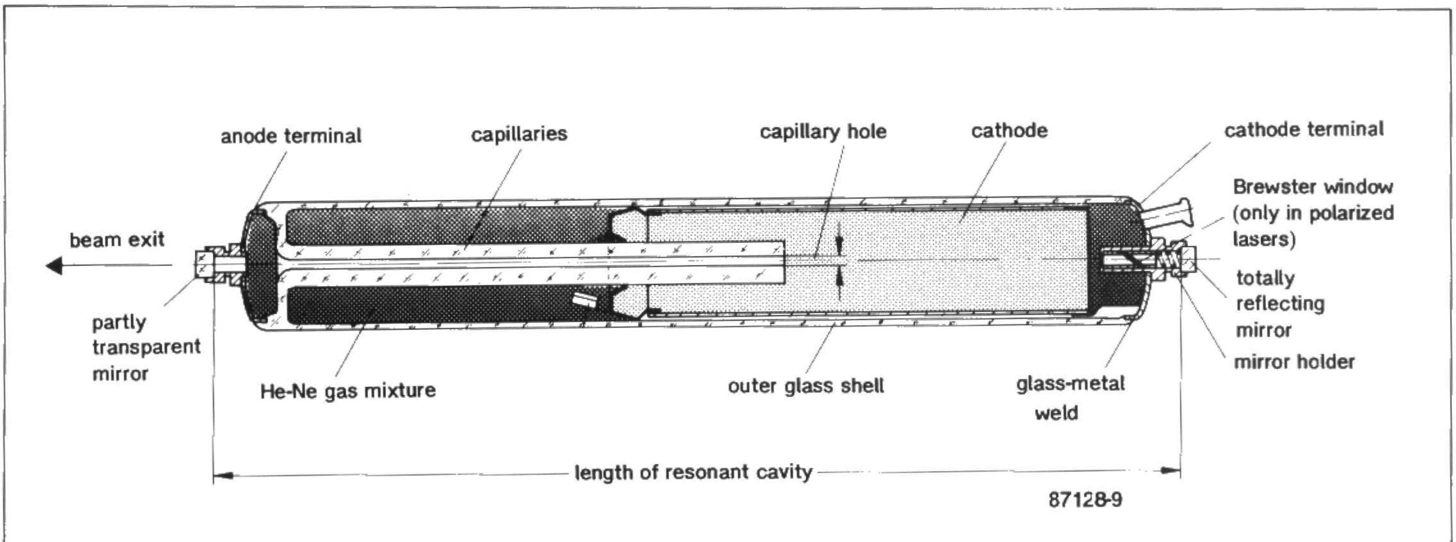


Fig. 7. Cross-sectional view of a He-Ne laser (courtesy of Siemens).

Users of light

Optocouplers, sometimes called opto-isolators, are devices that consist basically of a light-emitting diode and a phototransistor that are optically coupled within a light-excluding case. Optocouplers may be used with digital or analogue signals. They are normally specified by their isolation voltage (also called common mode rejection – CMR), speed (propagation delay), and forward coupling, normally called current transfer ratio – CTR. A typical, good-quality optocoupler has a CMR of about 2 kV, a propagation delay of around 5 ns, and a CTR, expressed as the ratio of the output current to the input current, of 30%.

Alarm and security systems often depend on the combination of an optoelectronic sensor and emitter, usually operating with infra-red light. Such systems may use a single or dual light-beam transmitter-receiver, in which the receiver is switched on to actuate an alarm when the beam from the transmitter is broken by an object. There are also systems that operate by reflecting the light beam back to an integral light emitter-sensor with the aid of a prismatic mirror (which simplifies alignment as compared with a plane mirror).

Infra-red remote control systems for use with TV receivers and audio systems, to name but a few, also use a transmitter (hand held) and receiver (located in the equipment to be controlled). The transmitter is usually controlled by a five-bit (for 32 codes) or a six-bit (for 64 codes) keypad. The code is transmitted by a number of IR LEDs. The coded signals are received by a photocell and fed to a decoder in the receiver. The decoder usually provides both digital outputs (channel changing, loudspeaker muting) and analogue outputs (volume control).

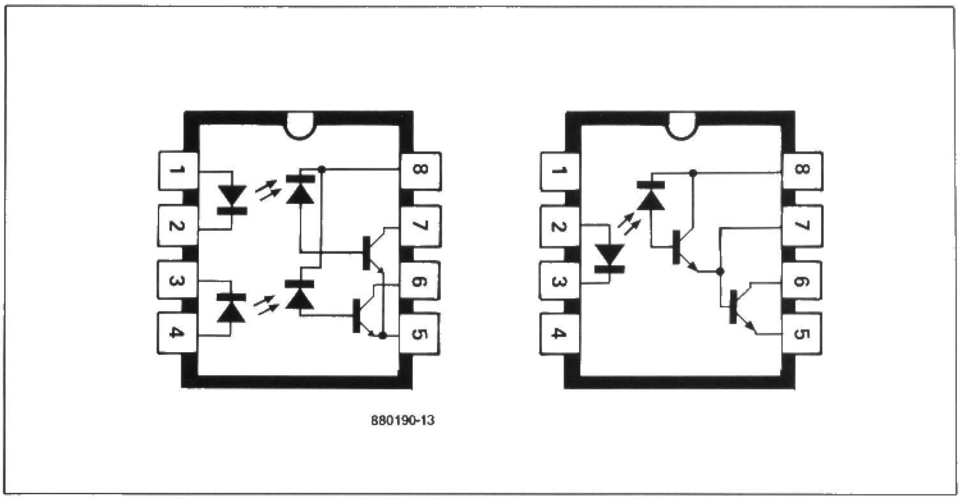


Fig. 8. Outline drawings of two types of optocoupler; the one on the right uses a darlington phototransistor for increased sensitivity.

The future

As already stated in the introduction to this article, Britain is in the forefront of optoelectronic research and development. Unfortunately, many companies in the industry find it increasingly difficult, even more so than other electronics concerns, to find suitably trained and qualified staff.

In line with the increased outward looking of the optoelectronics industry is the widespread participation in European research programmes such as EUREKA, ESPRIT, and RACE in order to spread the cost of R&D. There is, furthermore, a growing co-operation between optoelectronics companies and universities, actively encouraged by the government. Of the many universities, particularly Heriot-Watt and Southampton Universities are in the vanguard of optoelectronics research. Moreover, the Royal Signals and Radar Establishment – RSRE – at Malvern is one of the world's leading defence research establishments. The Government has set up Defence Technology Enterprises (DTE) to exploit commercially the research undertaken at places such as RSRE. The Government has also co-operated in the setting up of the Optical Sensor Collaborative Association – OSCA.

Apart from well-established companies such as Plessey, GEC, STC, Barr & Stroud, Ferranti, and many others, a fairly new powerful force in the British optoelectronics industry is British Telecomms' joint venture with the American giant Du Pont, called BT&D Technologies.

Most of the British industry is moving towards metallorganic chemical vapour deposition – MOCVD – manufacturing techniques that will make possible true mass production of complex optoelectronic devices.

There also appears to be a bright future for non-linear optical switches made from lithium niobate. Barr & Stroud, a Pilkington company, markets a range of lithium niobate optical ICs, including phase modulators, intensity modulators, and directional couplers operating in the IR region.

Although the UK is not so strong in laser manufacture, Philips Components, formerly Mullard, supplies most of the CD lasers required by its parent company Philips of Holland.

The largest producer of thermionic valves in Europe is EEV, a GEC company. Apart from thermionic valves,

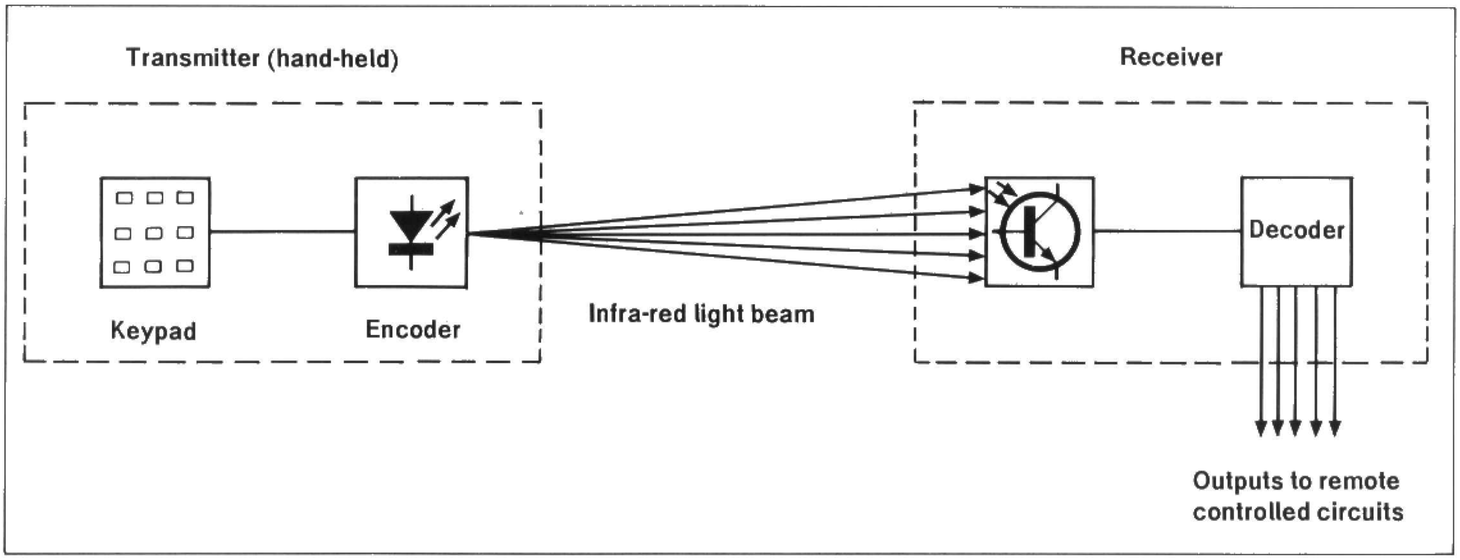


Fig. 9 Basic outline of an infra-red remote-control transmitter-receiver.

this company, which employs 2,700 personnel and has annual sales of some £80 million, manufactures liquid-crystal displays (LCDs), charge-coupled devices (CCDs), and image intensifiers made in MOCVD.
Another worldleader is the Midlands company of Hadland, which designs and manufactures high-speed electronic cameras and image converters. One of their cameras is said to run at over 600 million frames per second!

Pundits reckon that the world market for optoelectronic devices will grow from under £300 million in 1987 to around £800 million by 1992. Given the state of our research and development, there must be many rich pickings there for the British optoelectronics industry.

References

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2. *Lasers: an overview,* Elektor Electronics, July-August 1987, p. 27.
3. *The razor edge of the excimer laser,* Elektor Electronics, February 1987, p. 36.
4. *Photonics,* Elektor Electronics, March 1986, p. 46.
5. *Optoelectronics Applications Manual,* McGraw-Hill, 0-07-028605-1.
6. *Optoelectronics Circuits Manual,* by R.M. Marston, Heinemann, 0-434-91211-5.

OPTOELECTRONICS BRIEF

A very Intelligent Computer Terminal

by Bill Pressdee

Over the last decade the thrust of innovation in information technology has moved gradually from mainframes towards minicomputers and specialist workstations. It is not surprising, therefore, that intelligent terminals systems development is now of considerable interest.
Lynwood Scientific Developments [1] of London, which claims to be the first independent European company to embed a microprocessor in a video display unit, is a world leader in the design and manufacture of sophisticated display technology. Moreover, it has an enviable reputation in the development of specialized systems for meeting clients' specific needs and for forming joint teams with them.
Nevertheless, it has a low market profile, possibly because it is involved in military projects with a high security classification. In fact, one is more likely, perhaps, to come across an original Lynwood terminal to which a major electronics manufacturer has attached its logo.
The philosophy adopted by Lynwood in manufacture involves concentrating operations into three specialist units: short run special products, such as those built for the Ministry of Defence; high volume runs; and production of logic boards and sub-assemblies. The company is unusual in today's world of volume output in that it maintains an extensive capability for specialized systems complementary to its hardware development.

The j300 enables graphics to be shown together with file data — a possible extension to a criminal records facility.

Sophisticated communications software

The successful Lynwood Alpha and Beta terminals have now been superseded by the latest range: the j102, j300, j500 and j700. Based on the Alpha terminal, these new displays represent an updating with a large number of systems uses in mind. The new Lynwood j300 high definition, intelligent display has an embedded Zilog Z8001 processor and 256k of display memory that enables sophisticated video and communications software to be used. Programs can be supplied for two or three emulators to operate within the same terminal concurrently, using split or virtual screens. Other programs can support a variety of communications protocols.

Through multiple ports, simultaneous communications can be maintained with separate host computers. Attached peripherals which make up the workstation for a system—such as various types of reader, letter quality printers, security devices and dispensers—can be controlled by the terminal, and the display can be used for local calculations or to execute terminal resident tasks.

The unit is compact and great attention has been paid to sound ergonomic design. Considerable care has also been taken in the placement of components which, coupled to the optional provision of fibre optic interfaces, is a clue that the company also supplies a version of the j300 to full Tempest security specification.

Banking applications

The largest terminal is a 482 mm colour display with a resolution of 1280 by 1024 4-bit pixels. Graphics functions are executed by a powerful controller assisted by the terminal's Motorola 68010 processor incorporating a 2 Mb memory. Optionally, a Motorola 68020 and a 4 Mb memory can be provided. A large frame buffer can hold three 1280 by 1024 displays and the screen image may be built from selected parts of the frame buffer. This arrangement is designed for command and control applications where a static 16-colour geographic background can be overlaid with another 16-colour plane of dynamic information.

A system developed by Lynwood, initially in conjunction with the United Bank of Kuwait, has recently been adopted by a number of other banks in the Middle East. This sophisticated on-line teller system can display at a teller position all relevant account details and authorized signatures appropriate to an account.

The records are created via the signature capture station, using a facsimile reader in conjunction with a j300 which has a security badge reader so that an audit trail of signature entry and authorization can be recorded. The informatiin is sent as an ASCII alpha string to a database held on a separate processor that interfaces to whatever host processor the bank may use.

In another application Lynwood is providing integrated dealer workstations to various banks including the United Bank of Kuwait. These provide a number of screens controlled by a single keyboard and by virtue of its excellent emulation and communications programs, information from a plethora of sources can be co-ordinated and correlated.

They may be from in-house computers such as IBM, DEC, DG, Tandem, ICL and NCR or external networks, from Telex, via service gateways, and external services, such as Reuters, Telerate, Topic and Datastream while a page cache can be held within the workstation. Text and graphics can also be displayed on a common screen and controlled from the keyboard.

Machine-readable passports

Another interesting use for the terminals is a machine-readable passport system developed in conjunction with De La Rue, the leading currency and passport printer, and marketed by De La Rue Identity Systems [2] of Basingstoke. It enables laborious manual infilling to be replaced by a flexible issuing system which is much faster and automatically logs the number of passports issued. At the point of entry to a country, immigration throughput is greatly improved and monitored information may be automatically recorded leading to improved security and control of visitors.

Lynwood terminals have enjoyed considerable popularity with metropolitan police forces in the United Kingdom and other parts of the world. The terminals used in the London police system have been upgraded to interface with the X25 networking protocol of METNET.

The facility for multi-emulation enables the terminals to tap a number of resources to provide a criminal record information system with inputs from the Police Command network, the Police National Computer, and HOLMES, the Home Office serious crime investigation matching profiles dossier. These can be correlated on a single video display unit (VDU). At present, photographs of criminals have not yet been introduced into such system but it is only a matter of time as the technology is there to be used.

Terminals such as the j300 contain sufficient memory and processing power to have a significant effect on the overall system design. Not only can they help to reduce some of the problems, mainly concerned with real time, that are associated with certain types of computer system, but they can also provide a much more effective man-machine interface that can be tailored to the needs of individual users.

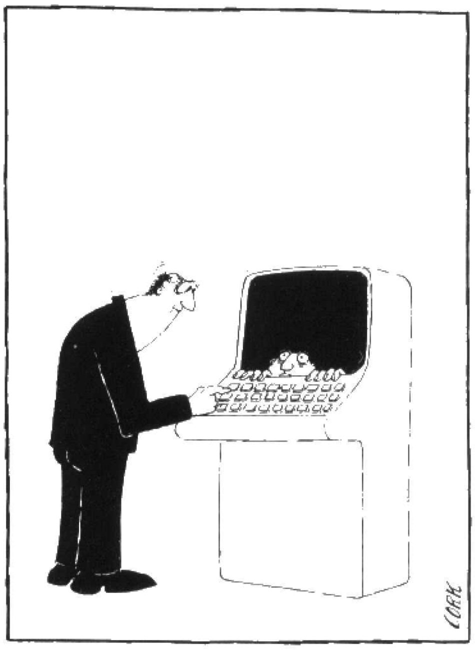
To harness the hardware, the company has developed a range of software that is flexible in its approach to both communications and emulations. In addition, the company has examined specific applications to determine whether generalized packages can be developed that are project independent and capable of handling the hardware in a very flexible manner.

One of these, TRAPS, is a terminal-resident software package that enables a format-driven dialogue to be generated at the terminal. With the use of its processing power and memory, the most effective dialogue is produced while minimizing the demands on the host processor and communications network. Format-driven dialogues are particularly successful because they enable the user to be led through a set procedure with the input data being validated at all stages. Keystrokes and entry time are reduced by using prediction tables that anticipate character string matching within the validation.

References.

(1) Lynwood Scientific Developments Ltd, Unit Five, Bowling Green Lane, London EC 1R 0BD.

(2) De La Rue Identity Systems Ltd, De La Rue House, Basing View, Basingstoke RG21 2EL.



HARMONIC ENHANCER

by W. Teder

An harmonic enhancer, or exciter, generates harmonics from, and superimposes these on to, a music signal that has none, or few, of these overtones. In that sense, it is a sound-correcting device that adds warmth to a sound.

The principle of the operation of an exciter is shown in Fig. 2. Part of the original signal is fed to a variable clipper, whose cut-off frequency can be set from 1-5 kHz. The filter output, whose amplitude should not exceed 10% of that of the original signal, is then recombined with the original signal.

The basic set-up in Fig. 2 may be modified and refined in various ways. It is, for instance, possible to make several of the filter parameters adjustable externally, but for most relatively simple needs this sophisticated approach is not really necessary. Moreover, the filter might be preceded by a compressor circuit and followed by an expander circuit. This method obviates the serious distortion caused by short signal peaks and also ensures that the harmonic content does not vary too greatly with the input level. Whatever refinements or modifications are introduced, they lead to a unit with may operational possibilities, all of which have to be set up carefully.

The enhancer described here is intended as an experimental unit for use by the constructor to become acquainted with the basics of the harmonic enrichment effect. None the less, the unit may, of course, be expanded as required at a later date.

The harmonics caused by the clipping are mainly odd-order ones. After they have been recombined with the original signal, the resulting sound is only little louder (about + 1 dB), but, as already stated, it is warmer, more mellow. The new sound may, however, just be distorted if, for instance, the cut-off frequency of the clipper is set low, i.e., at 1 kHz, and the level of the harmonics is much higher than 10% of that of the original signal. Used with electric guitars, this may not be unacceptable, but it certainly would be with a good audio amplifier.

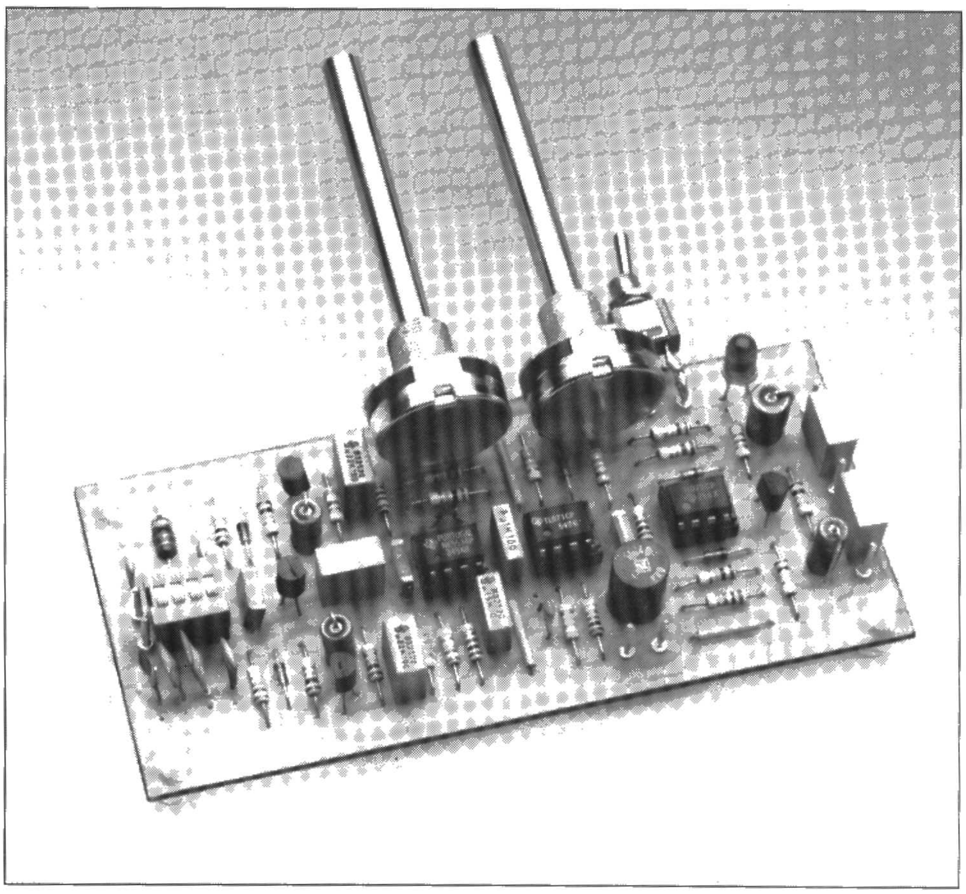


Fig. 1. General view of the Harmonic Enhancer.

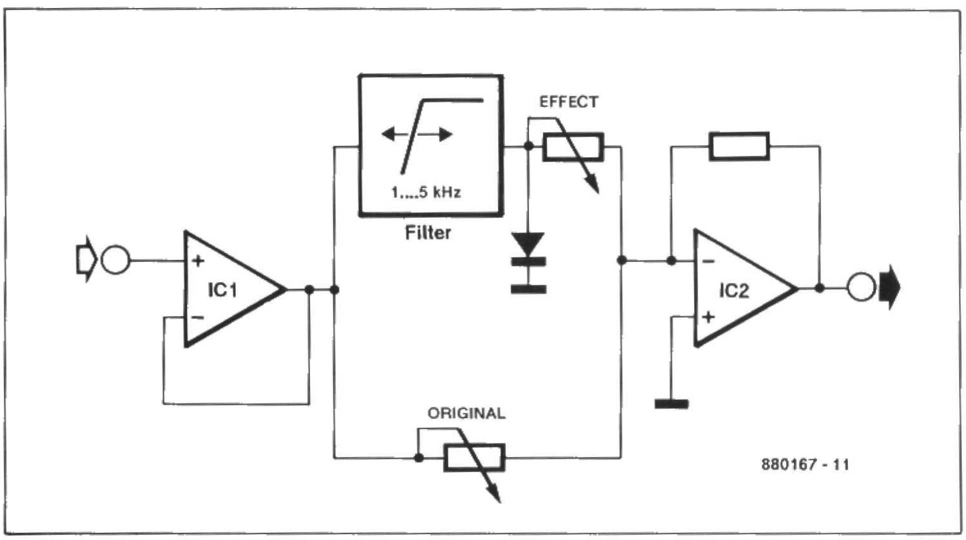


Fig. 2. Block schematic of the Harmonic Enhancer.

Circuit description

The circuit of the basic enhancer is shown to the right of the dashed line in Fig. 3. It is based on two integrated cir-

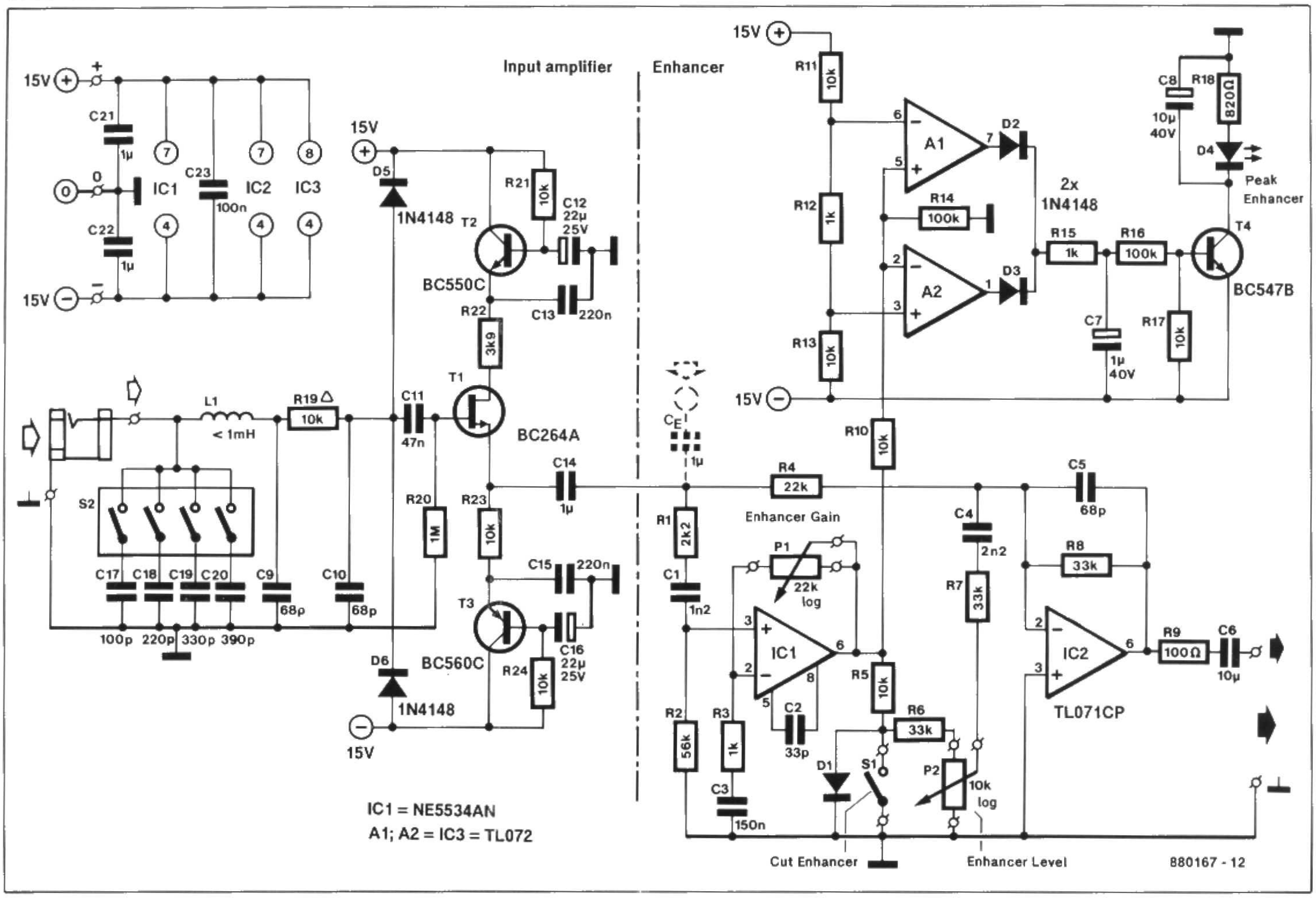


Fig. 3. Circuit diagram of the enhancer (to the right of the dashed line), and the impedance inverter for use with guitars.

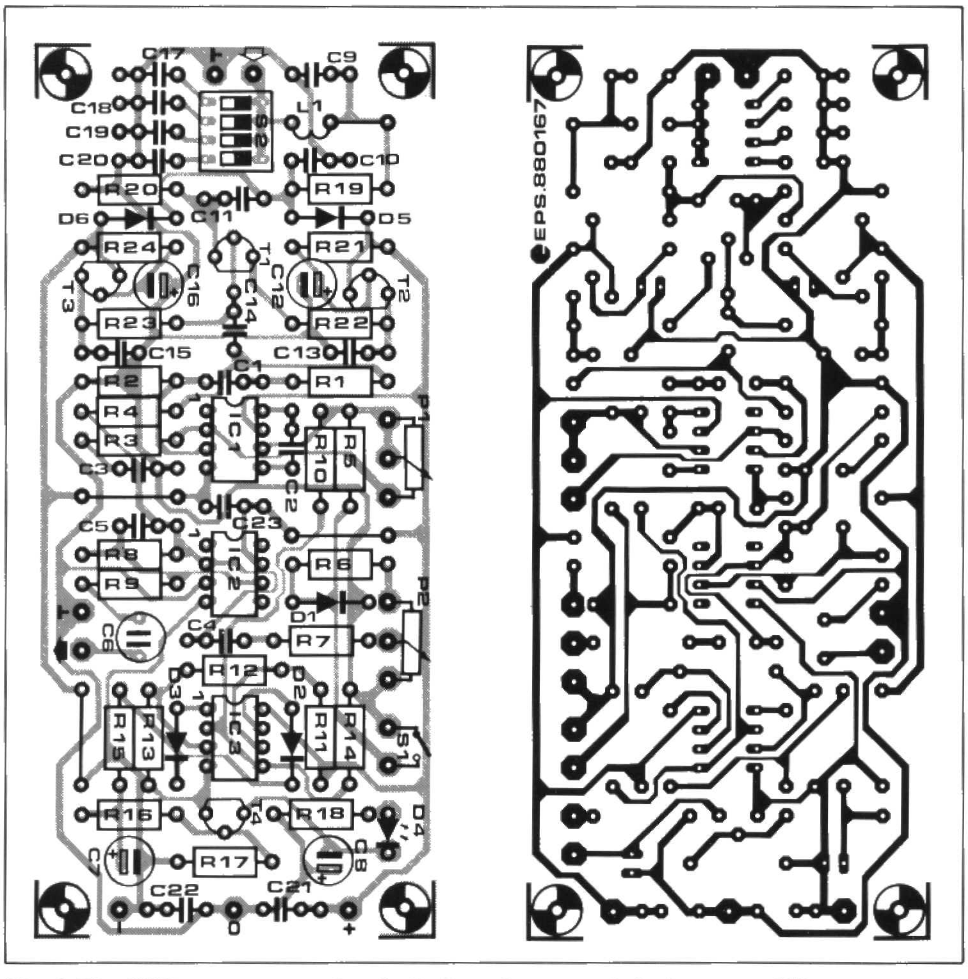


Fig. 4. The PCB can accommodate both the enhancer and the input amplifier.

Parts list

Resistors (± 5%):
R1 = 2K2
R2 = 56K
R3;R12;R15 = 1K0
R4 = 22K
R5;R10;R11;R13;R17;R21;R23;R24 = 10K
R6;R7;R8 = 33K
R9 = 100R
R14;R16 = 100K
R18 = 820R
R19 = 10K; metal film
R20 = 1M0
R22 = 3K9
P1 = 22K or 25K logarithmic potentiometer
P2 = 10K logarithmic potentiometer

Capacitors:
C1 = 1n2
C2 = 33p
C3 = 150n
C4 = 2n2
C5;C9;C10 = 68p
C6 = 10μ; bipolar; radial
C7 = 1μ0; 40 V; radial
C8 = 10μ; 40 V; radial
C11 = 47n
C12;C16 = 22μ; 25 V; radial
C13;C15 = 220n
C14;C21;C22 = 1μ0; 63 V
C17 = 100p
C18 = 220p
C19 = 330p
C20 = 390p
C23 = 100n

Semiconductors:
$D_1;D_2;D_3;D_5;D_6$ = 1N4148
D_4 = red LED
T_1 = BC264A+ (Philips Components)
T_2 = BC550C
T_3 = BC560C
T_4 = BC547B
IC_1 = NE5534P
IC_2 = TL071CP
IC_3 = TL072CP

+Listed by Cricklewood Electronics.

Miscellaneous:
L_1 = max. 1mH0 (see text)
S_1 = miniature SPST switch. S_2 = 4-way DIL switch block.
PCB Type 880167 (see Readers Services page).

cuits, IC_1 and IC_2.
The signal is applied to low-noise amplifier IC_1 via C_1 and R_1, which form a high-pass section with a cut-off frequency of 2.4 kHz. Further attenuation of frequencies below 1 kHz is provided by high-pass section R_3-C_3.
After amplification (gain is set by P_1), the high-frequency part of the signal is clipped asymmetrically by R_5-D_1. The distorted (i.e., rich in harmonics) signal is applied to the inverting input of IC_2 via P_2 and a further low-pass section, R_7-C_4. The effect signal may be switched off by S_1.
Also applied to the inverting input of IC_2 is the original signal (via R_4).
Since a too high amplification of the effect signal leads to audible distortion, a peak meter has been added. This consists of opamps A_1 and A_2, which form a window discriminator, and T_4. The reference voltages for the window (pins 3 and 6 of IC_2) are derived from divider R_{11}-R_{12}-R_{13}. The output voltage of IC_1 is monitored via R_{10}. If this lies outside the window potentials, capacitor C_7 is charged via R_{15} and transistor T_1 switches on peak warning light D_4. Capacitor C_8 in the collector circuit of T_4 extends the operation of D_4, so that even short peaks are indicated. The setting of P_1 is optimum when D_4 flickers during signal peaks.
The cut-off points of high-pass sections R_1-C_1 and R_7-C_7 have been determined emperically with the aid of an electric guitar.
The harmonic content can be controlled satisfactorily when the unit is used with an electric guitar. If the enhancer is for use with hi-fi or PA equipment, the values of C_1, C_3 and C_4 should be halved. It is, of course, also possible to experiment with a high-order variable filter at the input circuit of IC_1.
If the threshold of operation of D_4 is found too high, the value of R_{12} may be reduced as required. This is conveniently done with a 500-ohm potentiometer in series with a 470-ohm fixed resistor.
If the enhancer is intended for use as a guitar effects unit, the amplifier to the left of the dashed line in Fig. 3 is recommended. Strictly speaking, this is an impedance inverter, based on a FET, which has been designed specifically for use with a guitar pick-up.
The input consists of two low-pas sections, L_9-C_9 and R_{19}-C_{10}, which effectively prevent interference from HF equipment. In a non-critical environment, L_1-C_9 may be omitted.
Diodes D_5 and D_6 protect the input against too high voltages.
The signal is taken from the low-impedance source of T_1 and applied to the enhancer via C_{14}.
The circuits around T_2 and T_3 provide further smoothing and filtering of the power supply lines.
DIP switch S_2 facilitates matching to various cable lengths, which, of course, is a boon for many musicians. With values of capacitors C_{17} to C_{20} as shown, cable lengths of 1 to 10 m may be accommodated.

Finally

The enhancer and input amplifier for guitars may be conveniently constructed on the PCB shown in Fig. 4.
Although the circuit shows a mains-operated power supply, a ± 9 V battery supply may also be used if only the enhancer and input amplifier are used. Rechargeable 9 V batteries will give about 6 hours continuous use, while two PP9 batteries will give about 25 hours.
It should, however, be borne in mind that in view of the supply current of around 20 mA it is advantageous to use a mains supply. This is even more so if other modifications are incorporated.

NEWS

Display for clearer outdoor viewing

The first high-contrast reflective electronic display for outdoor use has been introduced by Racal Microelectronic Systems. Using a new LCD technology, developed by Racal, it offers a wide viewing angle and is designed to be set up on station platforms, in highly glazed areas in airports, and other locations where there is a high ambient light level. Unlike conventional LCD technologies, the new display does not require polarizing films. It also dispenses with back-lighting and operates at a low power level (less than 10 watts for a six-line, 30-character sign).

Racal Microelectronic Systems • Worton Drive • Worton Grange Industrial Estate • READING RG2 0SB.

£1 million MoD order for Schlumberger

Schlumber Instruments has won an order valued at more than £1 million for the supply of multimeters from the Ministry of Defence.

John Emerson (left), managing director of Schlumberger Instruments, is seen here with Mr John Surtees, a representative of the MoD, at the acceptance meeting ar Farnborough.

Schlumberger Instruments • Victoria Road • FARNBOROUGH GU14 7PW.

Tripods for video cameras

A range of lightweight tripods and associated pan-and-tilt heads for use with news and field-production video cameras has been introduced by W. Vinten.
The innovaroty two-stage *ENG* tripod provides a quick-action rigid platform with a heigt range of 42 to 157 cm, yet folds to a length of only 68 cm. It weighs only 3 kg.

W. Vinten • Western Way • BURY ST EDMUNDS IP33 3TB.

1553B field bus in operation

As part of a world-wide initiative to establish an international field bus standard, ERA Technology has completed the first phase of a 1553B Field Bus trial system. This is installed and operating at a Severn Trent Water Authority water treatment plant.
The ERA development, supported by a collaborative group of 17 companies, demonstrates the capabilities of the 1553B Field Bus in meeting the requirements of the ISA SP50 functional guidelines for the emerging H2 field bus standard.

ERA Technology • Cleeve Road • LEATHERHEAD KT22 7SA.

NEWS

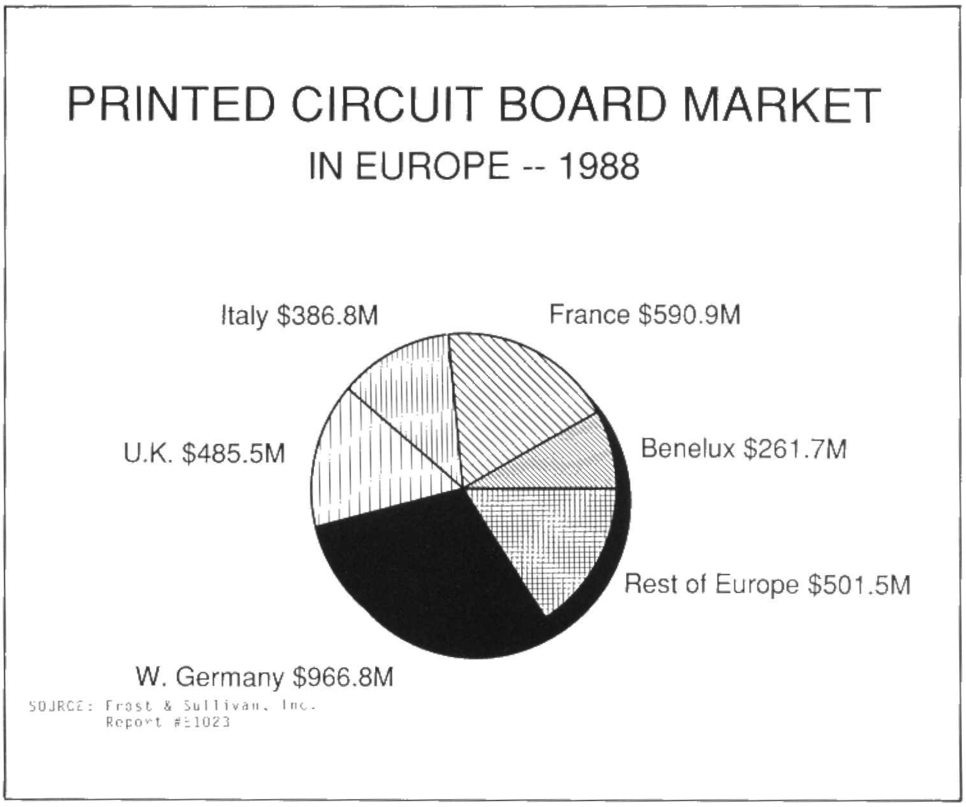
Healthy PCB market in Europe

Flying tails form the fastest moving sector of the expanding PCB market in Europe, according to *Printed Circuit Board Market in Europe**. A flying tail is a type of flexi-rigid board of which a single rigid area has one or more flexible tails to provide connections to off-board components.

The European PCB market grew by 8.4% in 1987 (to over $3 billion) and is predicted to expand to nearly $4.5 billion by 1992. The fastest growing end-use market is the automotive industry.

Of the 2000+ PCB manufacturers in Europe, the most successful are the small to medium sized companies that join forces to provide all-round supply capabilities.

Market analysis report E1023 from Frost & Sullivan • Sullivan House • 4 Grosvenor Gardens • LONDON SW1W 0DH.



Secure communications processor

The government's computer security authority (CESG) has granted formal certification to a secure communications processor said to be the first of its type in the world, developed by GEC Plessey Telecommunications – GPT. The development work was sponsored by the Royal Signals and Radar Establishment (RSRE) at Malvern.

As more and more computers are linked together, the dangers of information being stolen, corrupted, or leaking out are growing. Areas for particular concern are financial institutions, where there have already been examples of poor computer security resulting in substantial financial loss, and in government, where national security may be under threat. The purely financial cost of losses arising from breaches in computer security can be enormous. A survey in France in 1986 found that there had been losses of some £700 million in one year, while one in the USA put the cost there at $5 billion in a single year.

GEC Plessey Telecommunications • PO Box 53 • COVENTRY CV3 1HJ.

First voice controlled videotex

The latest voice recognition technology has enabled Teletext TV sets and telephones to be combined to produce the first voice-controlled videotex system.

The new Televox system, introduced by McCallum Televox from Cambridge has the ability to combine televised text and audio messages without the need for special equipment. While a particular page of an existing Teletext TV system is on the screen of a user, voice commentary and descriptions can be sent over the telephone.

In contrast to ordinary broadcast Teletext systems, which operate on a 'carousel' basis with intervals of many seconds while a viewer waits for a selected page to appear, Televox provides the user with an individual path through the pages, with instant changes following voice commands into the telephone handset.

When a user calls the Televox control centre, a subscription period is initiated which lasts for the duration of the call. The caller is then asked to repeat a few control words to enable the system to accept their pronunciation. The voice recognition system of the control computer is then commanded by simple combinations of these words to select pages of text from a potentially very large database, which are broadcast to the caller's TV set.

The Televox central computer system comprises some 50 PC-type processors running sub-systems which are interconnected by a local area network, in a modular arrangement which can be readily expanded to provide for growth in demand.

Its originators are now planning to licence the Televox technology in other countries.

(McCallum Televox Ltd, Cambridge Science Park, Milton Road, CAMBRIDGE, CB4 4GG.

Precision microassembly workstation

A workstation for the development or small-scale production of a wide range of items needing microassembly, particularly in the field of fibre optics, is available from Sifam Ltd.

The microassembly workstation is designed for use with single-mode optical fibres and other assembly work, including laser and detector pigtailing, assembling microlenses and mounting fibres to a range of passive and active optical elements, including integrated optical modules.

Of modular design and highly automated, it can readily be adapted to a specific application, and is tailormade to a customer's specification. It is based on a robust precision-ground optical table onto which are mounted specialised modules according to the needs of the application. Many of them are controlled by an IBM microcomputer via menu-structured software.

The workstation can be used to splice optical fibres in a wide range of materials, dimensions and wavelengths, including dissimilar fibres, and can splice high-birefringence fibres with automatic polarisation-axis location.

A range of optical sources and detectors includes a local light-injection and -detection facility which allows optical power to be coupled into and out of a fibre without access to the ends: the power transmitted by a fibre during splicing can be monitored to optimise fibre alignment. Alignment is normally by automatically controlled piezoelectric microtranslation stages which can routinely achieve splices with excess losses or less than 0.1 dB.

(Sifam Ltd, Woodland Road, TORQUAY TQ2 7AY.

TRACKER-BALL FOR ATARI ST

by A. Schaffert

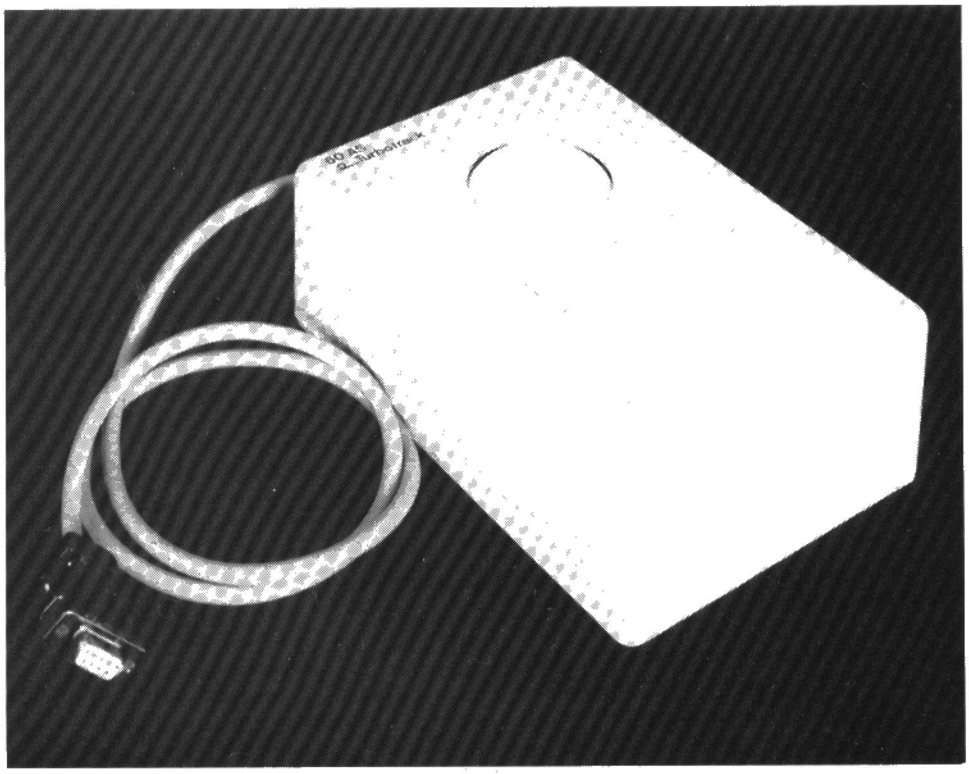
The use of a mouse for controlling a computer has become common practice. There may be a problem, though: space. It often happens that there is not enough room to move the mouse when the desk is littered with print-outs, pencils, notepads, books, diskettes and the odd cup of coffee. These space problems can be solved by the use of a tracker-ball, which is simply a mouse turned upside down.

The operation of a tracker-ball is basically identical to that of a mouse, but the ball movement is achieved via direct operation by the hand, rather than via the desk surface, or, if this is too smooth or slippery, the mouse pad. The principle of operation of the tracker-ball is clearly illustrated by the drawing in Fig. 1. Two spindles, fitted at right angles, drive encoder discs. Two opto-couplers are fitted for each disc, to translate the ball rotation into a logic signal. A small auxiliary spindle (visible in the photograph of Fig. 5) is provided on the home-made assembly to allow adjusting the height of the ball. To avoid slip between the ball and the 2 main spindles, the auxiliary spindle supports the ball just below the 'equator', so that its own weight keeps it in firm contact with the spindles.

Which direction?

The slotted opto-couplers are fitted such that when the light beam in one is interrupted by a black segment on the disc, the other just about 'sees' the edge of the next segment. This is shown in the drawing of Fig. 2. It should be noted that the slotted opto-couplers need not always be fitted as close to one another as shown — the essence is that two pulse trains are generated that are 90° out of phase.

The timing diagram of Fig. 3 shows how the phase relation between any two pulses in these trains enables the computer to deduce the direction of travel of the encoder disc. The signal from one opto-coupler is called *direction*, that of the other *clock*. Reading the timing diagram from the left to the right shows the order of the pulses when the ball is turned forward. Reading from the right to the left corresponds to turning the ball in reverse. Looking at *direction* during the rising edge of *clock*, it is seen that it is logic high for 'forward', and logic low for 'reverse' movement of the ball. Therefore, all the computer has to do is read the logic level of *direction* during the rising edge of *clock*. This is relatively simple to achieve by using an interrupt-routine. The general structure of such a routine is shown in the flow-chart of Fig. 4. The algorithm can also be be used for upgrading computers not equipped with a pointing device.



The ball assembly

Those not inclined to mechanical construction may, of course, buy a ready-made tracker-ball assembly, and skip this section altogether.

Use is made of an inexpensive billiard-ball with a diameter between 57 and 60 mm. No fixed guidance can be given for obtaining the remaining bits and pieces required to build the ball assembly, but a look in the junk box, or in a toy mechanics kit, may provide some good ideas.

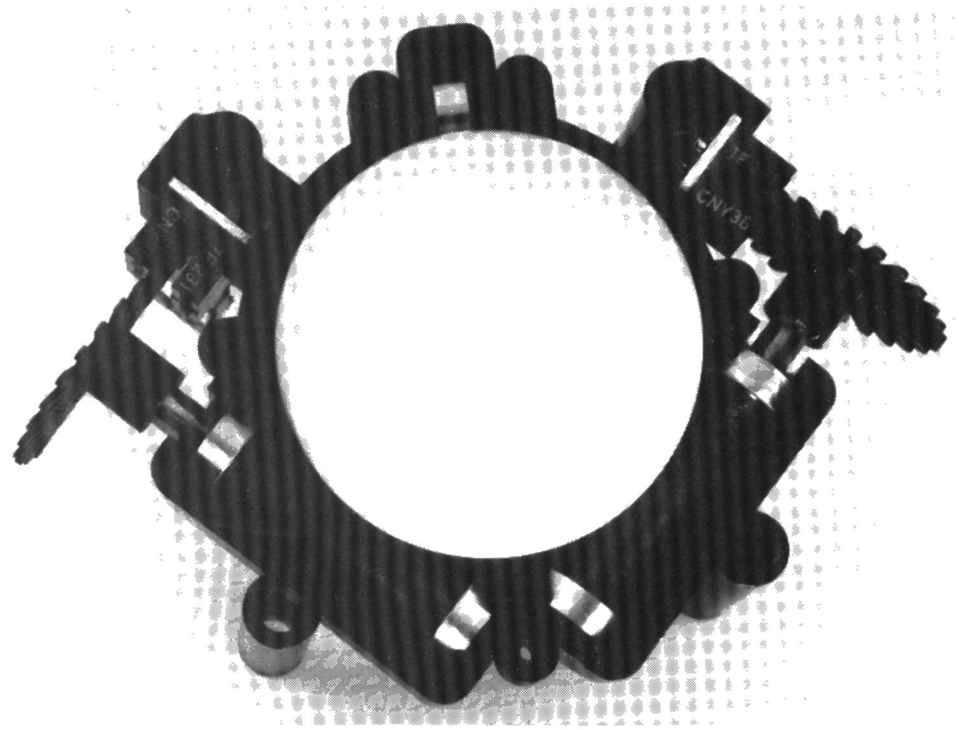


Fig. 1. This assembly holds the billiard ball, and translates its rotational movement into electrical signals (auxiliary bearing removed).

Any grease on the ball bearings used makes smooth movement of the ball impossible and should, therefore, be removed with a suitable solvent. To prevent rust, however, and to provide some lubrication, apply a few drops of light machine oil to the ball bearings. The spindles should have a diameter of about 10 mm, and a smooth and tough surface where the ball is supported. The encoder discs are mounted on to one end of each spindle. The disc is relatively simple to make from a small piece of translucent plastic, onto which 10 to 20 segments are drawn with the aid of of a black marking pen. The black segments should absorb the infra-red light sent out by the IRED in the opto-coupler.

Another, perhaps more elegant, way of making the encoder discs is to do this photographically. Make a drawing of the disc on a large sheet of paper. Photograph this twice with a pocket camera loaded with a black and white film (do not use colour slides, because on these

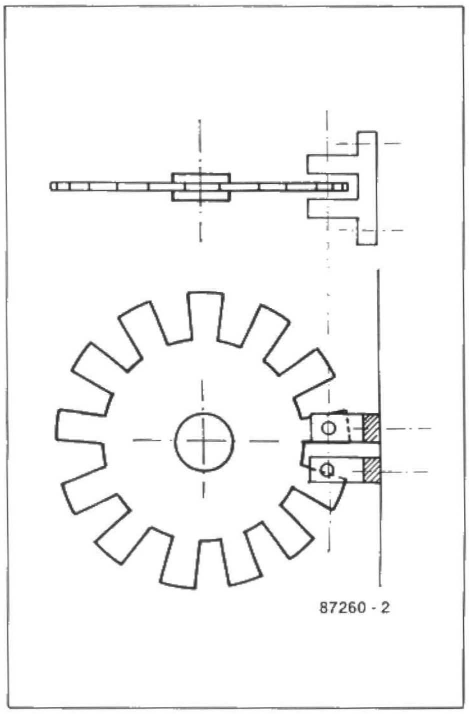


Fig. 2. Position of the two slotted opto-couplers. The cams on the encoder disc are simply blackened segments that interrupt the infra-red light beam.

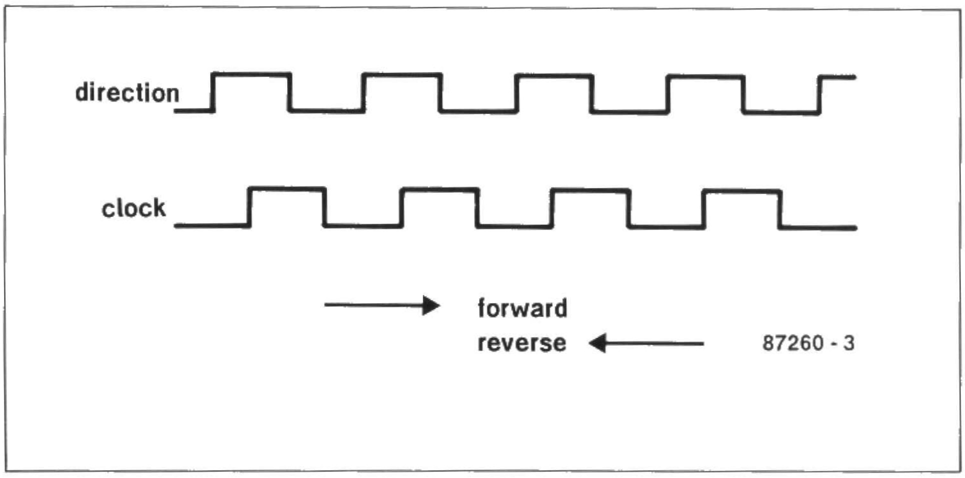


Fig. 3. The phase relation between the pulses provided by the opto-couplers is used for deducing the direction of travel of the encoder disc.

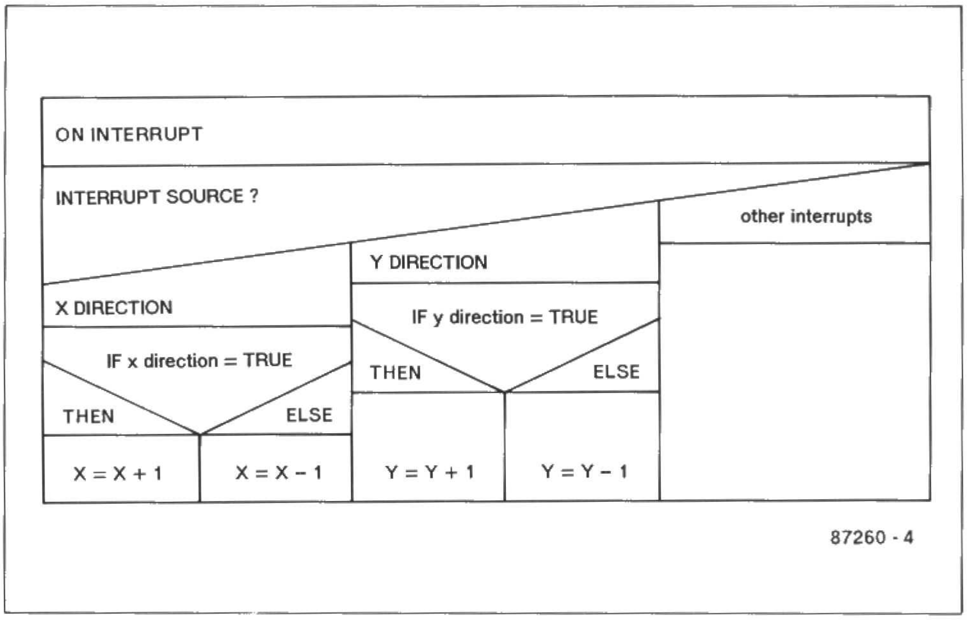


Fig. 4. Suggested flow-chart of an interrupt-based software driver for the tracker-ball.

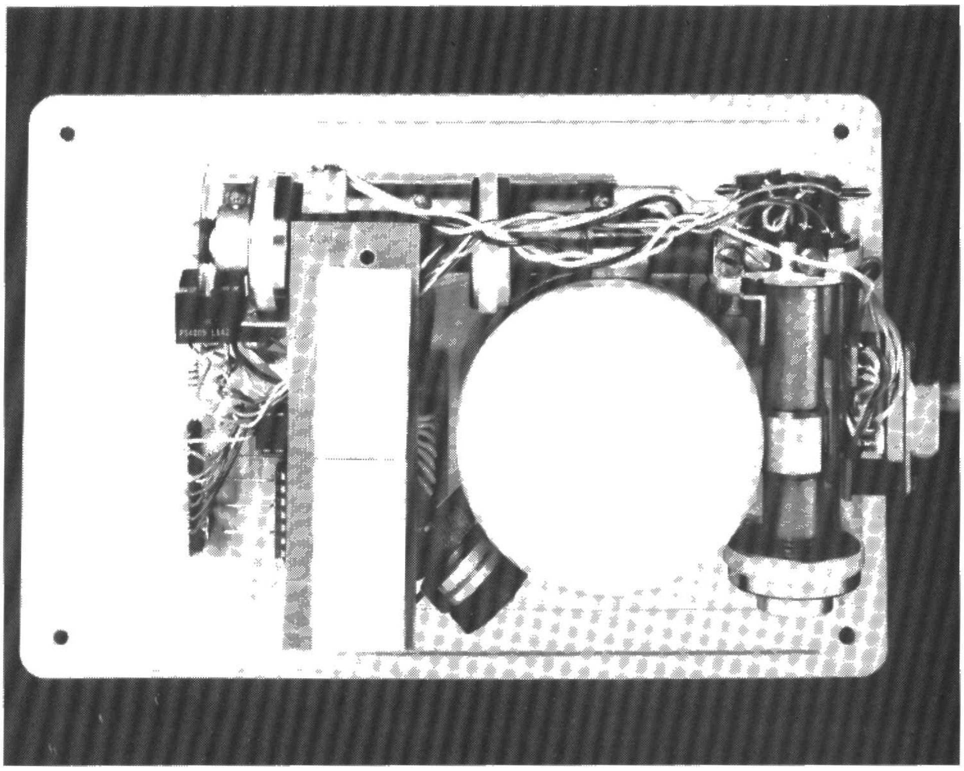


Fig. 5. Top view of the completed ball assembly. Note the auxiliary bearing in the lower left corner of the ball assembly.

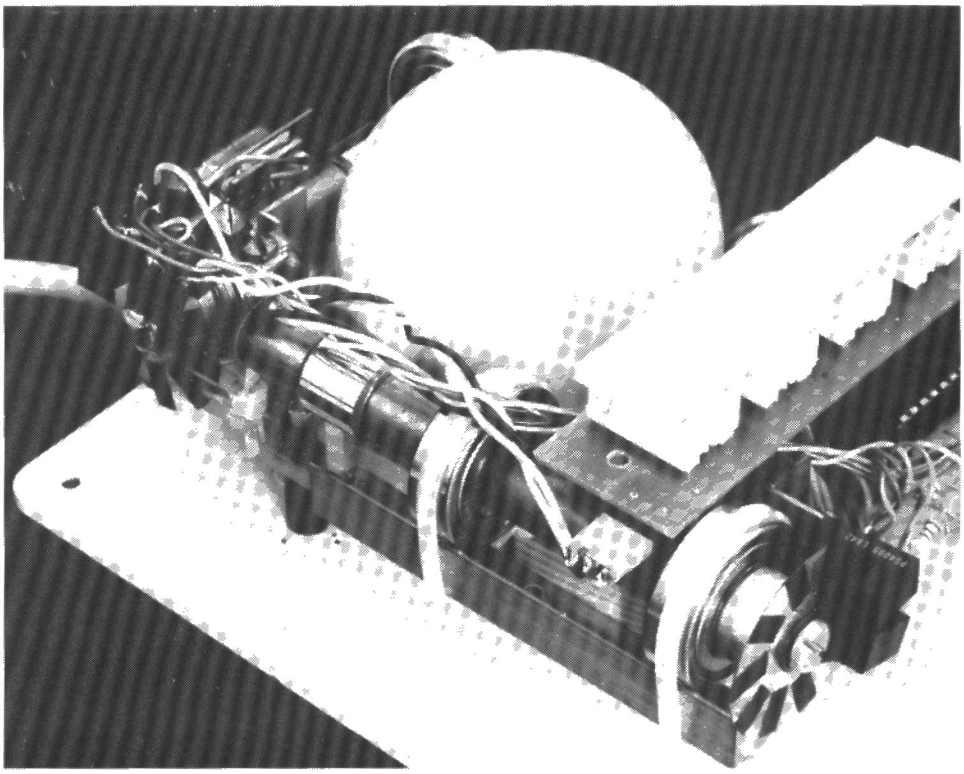


Fig. 6. Side view of the ball assembly, showing the ball bearings of one spindle secured on to the base plate.

black is translucent for infra-red light). The number of segments is a matter of personal preference. Generally, the more segments, the faster the cursor displacement (unless, of course, software is used for speed regulation). Relatively few segments, on the other hand, ensures better pointing accuracy of the tracker-ball.

The auxiliary bearing is simply a ball-bearing whose inside ring is clamped secure between two supports, while the outside, ball-supporting, ring can rotate freely. The position of the ball can be accurately adjusted by shifting the auxiliary spindle along an imaginary line that forms an angle of 45° with respect to the main spindles.

The completed ball assembly is best mounted on to a base plate of 85×125 ×4 mm, in which a hole is made of about 50 mm diameter to allow the ball to protrude at the underside. The base plate, which carries the complete mechanical assembly of the tracker-ball, is fitted on to the bottom lid of the enclosure by means of metal spacers. The accompanying photographs, Figs. 5 and 6, further illustrate the internal construction of the prototype.

Simple electronics

The circuit diagram of the tracker-ball interface is shown in Fig. 7. Although the circuit was designed to be compatible with computers in Atari's ST series, it may also be suitable for other computers provided that the mouse or pointing-device driver accepts the pulse trains supplied by the tracker-ball.

Each slotted opto-coupler is followed by a Schmitt-trigger and an open-collector driver. An additional, worthwile, feature is provided by bistable N_1-N_2 together with the diode-logic at its input. This part of the circuit makes it possible to connect the available mouse to K_1. The bistable selects the pointing device (tracker-ball or mouse) whose right button (RB) was last pressed. The tracker-ball is switched off by T_1 breaking the supply voltage to the photo-transistors. In the other situation, T_2 blocks, so that the supply voltage to the mouse is lowered by D_6. This makes it impossible for the internal opto-couplers to operate. Capacitor C_2 causes the bistable to select the trackerball at power-on.

When the mouse connection is not needed, simply omit T_1, T_2, K_1, R_6, R_7, R_8 and D_2 up to and including D_6. Install a wire link between the collector and emitter connections provided for T_1, and another wire link in position D_4.

When the Type CNY37 opto-coupler from Telefunken is not available, other, similar, types may be used instead, but some experimentation may be required to set the correct collector and/or IRED current by redimensioning R_1 to R_5. In this context, it is important to ensure that the Schmitt-triggers (N_3 to N_6) can reliably detect the difference between light and dark.

In the prototype, switches S_1 and S_2 (Right and Left button respectively) are each composed of two Digitast momentary action keys operated by a common cap. These switches may be mounted on to a small piece of prototyping board, which, in turn, is secured on to the base plate.

The tracker-ball interface is constructed on the printed-circuit board shown in Fig. 8. When, during testing, it appears that the cursor movement is opposite to that of the ball, the collector connec-

tions to the opto-couplers on the relavant spindles should be swapped.

Finally, an enclosure should be prepared to house the tracker-ball. As a suggestion, the introductory photograph of this article shows our completed prototype.

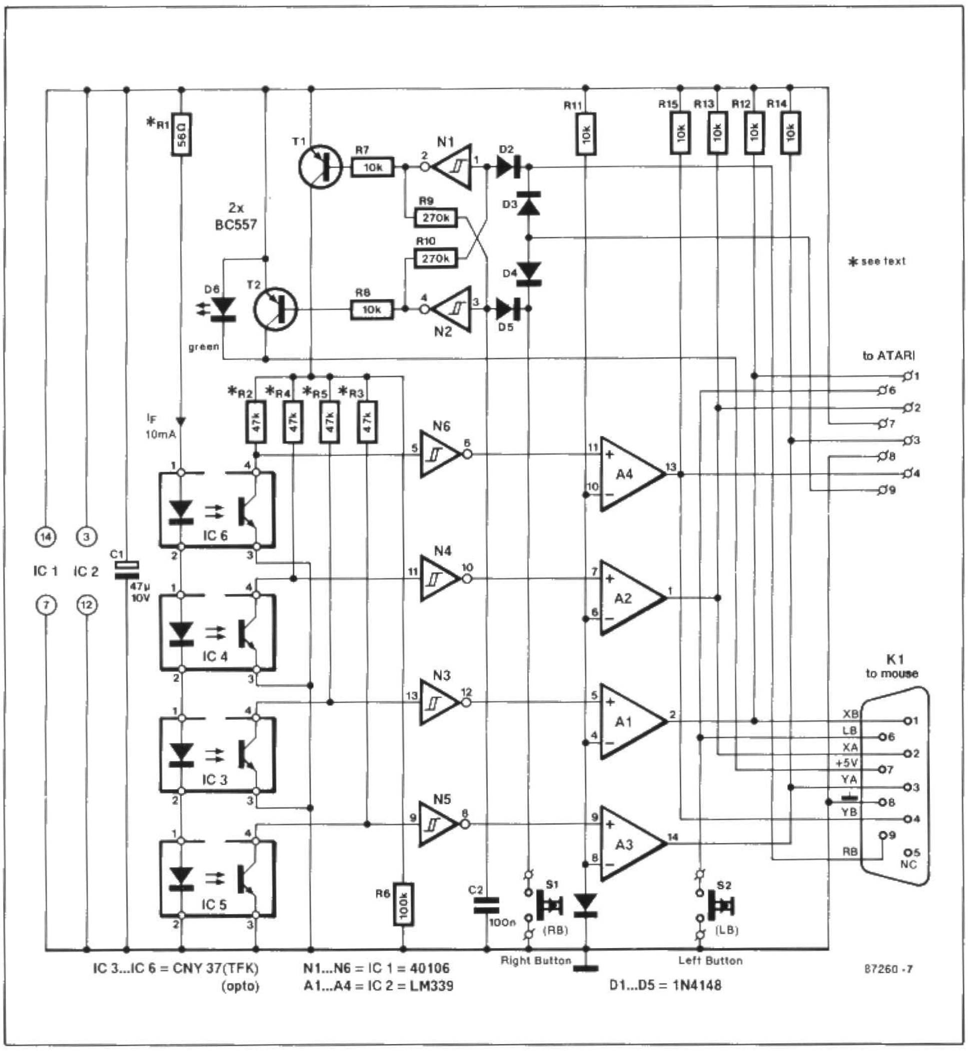


Fig. 7. Circuit diagram of the tracker-ball interface.

Parts list

Resistors (±5%):
R1 = 56R
R2 . . . R5 incl. = 47K
R6 = 100K
R7;R8;R11 . . . R15 incl. = 10K
R9;R10 = 270K

Capacitors:
C1 = 47µ; 10 V
C2 = 100n

Semiconductors:
D1 . . . D5 incl. = 1N4148
D6 = green LED
T1;T2 = BC557B
IC1 = 40106
IC2 = LM339
IC3 . . . IC6 incl. = general-purpose slotted opto-coupler; e.g. CNY37 (Telefunken; listed by Universal Semiconductor Devices).

Miscellaneous:
S1;S2 = two Digitast momentary action keys with common cap (ITW or ITT/Schadow).
K1 = 9-way male D-connector for PCB mounting.
PCB Type 87260 (not available ready-made through the Readers Services).

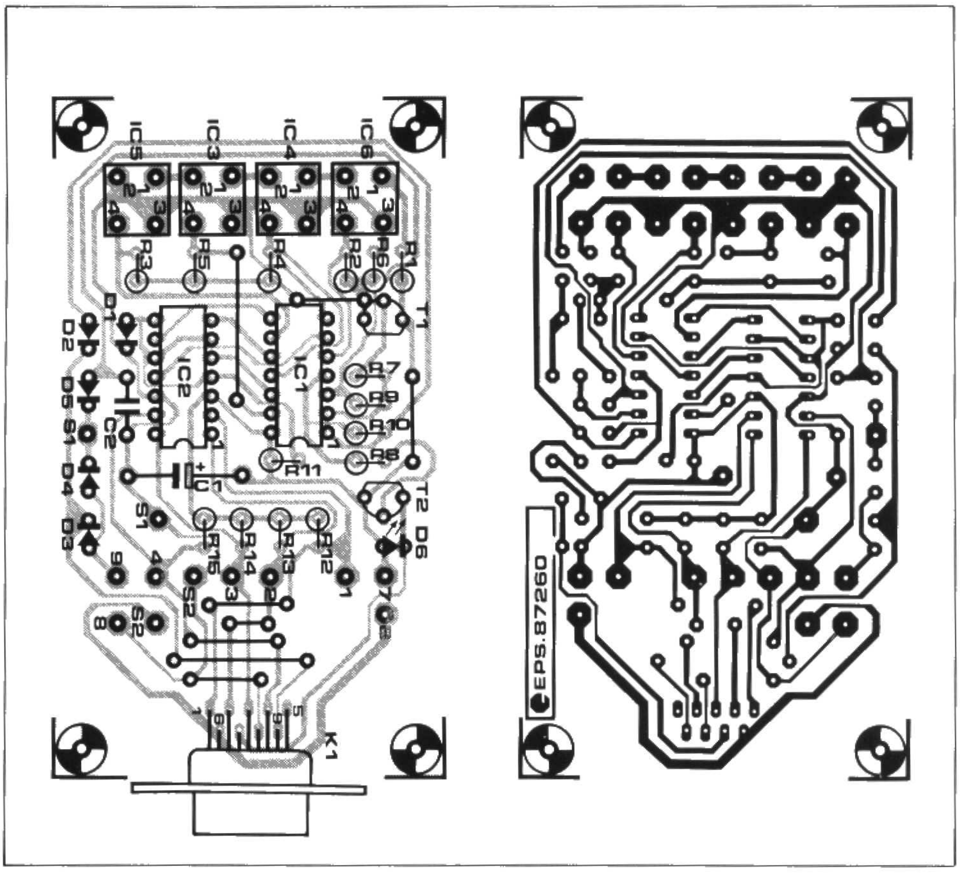


Fig. 8. Printed-circuit board for the tracker-ball for Atari ST computers. The mouse is connected to K1.

AUDIO & HI-FI BRIEF

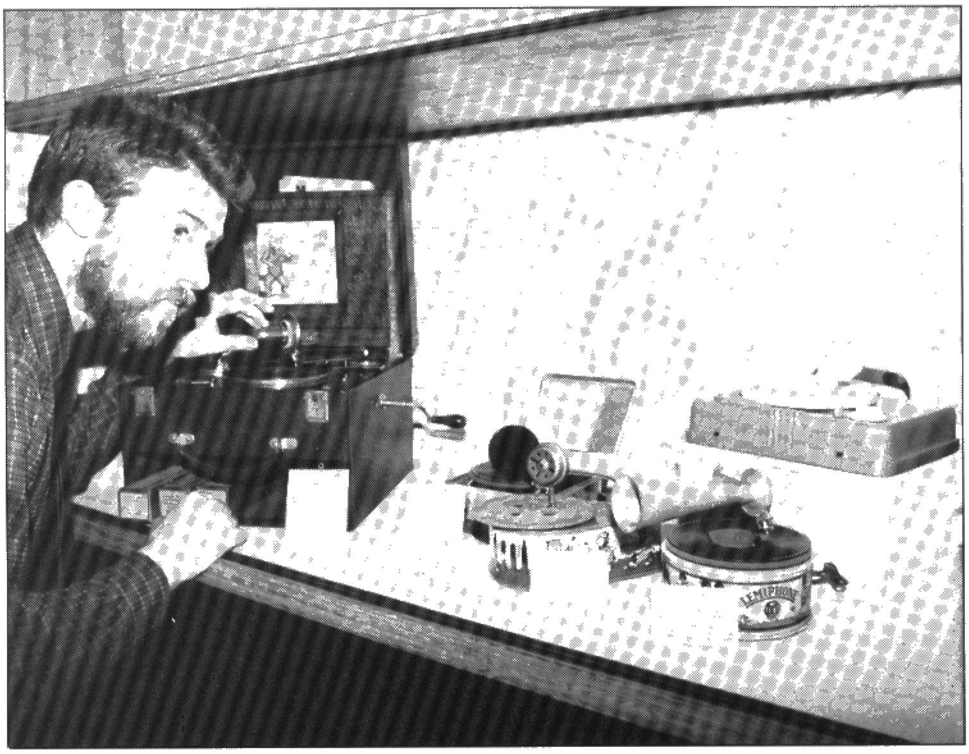
Sound Recordings Archive Covers the World

by Dr Jeremy Silver

Shortly before the outbreak of World War II, a young British music student went to his local record shop to buy a recording of Ernö Dohnányi's violin concerto. Unable to find a copy there, he decided to visit the British Museum, where he thought he would find a copy, at least, to hear if not to buy. To his amazement, he was told that gramophone records were not among the museum's magnificent collections.

Outraged, the student demanded an explanation, but when he was told that the director of the museum would come down to see him he left quickly. However, from the detachment of a public telephone he harangued the director on the importance of recordings in contemporary culture. The director agreed with the young man and told him to go away and do something about it himself.

After the war, the student, Patrick Saul, set to work and eventually became the first director of the British Institute of Recorded Sound (BIRS). In 1966, the BIRS moved to its present premises in South Kensington, the heart of London's museum district, and in 1983 it was absorbed into the organization of the British Library and became the National Sound Archive (NSA).



A display of early gramophones at the National Sound Archive, London.

Voices of the famous

Florence Nightingale, the reformer of hospital nursing; William Gladstone, the 19th century Liberal Prime Minister; and poets Alfred Lord Tennyson and Robert Browning are among the earliest famous voices preserved on wax cylinders. Others include Johannes Brahms playing one of his own compositions in 1889 and writer James Joyce reading from his *Ulysses* in 1924. Some of the earliest international recordings in the archive are those of aboriginal chants, made in the 1890s on wax cylinders in the islands of Australia's Torres Straits by anthropologist Sir James Frazer when he was writing *The Golden Bough* which influenced the modern attitude to the supernatural and religious ritual.

Dr Jeremy Silver is Head of Education and Publications, British Library National Sound Archive.

Today, NSA is a unique international resource for the study of all kinds of music, literature and the sciences. It collects recordings in every conceivable format—from cylinders to digital audiotape—and includes commercial recordings, broadcast material and field recordings.

It is a prime source for broadcasters, film makers, theatre companies, advertising agencies and the record industry as well as for academic researchers, actors, singers and composers.

Copies of all current British commercial records, including compact discs, are preserved, as is a vast back-catalogue of recordings many of which are not available anywhere else in the world. The NSA will also soon become the repository for recordings of all British parliamentary sessions in both the House of Commons and the House of Lords.

Early advertising

The scope of subjects covered is quite staggering. There is music of all kinds from classical and jazz to pop and traditional music from all over the world; spoken word recordings span political speeches, theatre performances and a large number of authors reading and discussing their own work.

There are also significant collections of oral history recordings, sound effects and industrial noise, as well as natural and wildlife recordings featuring more than 5000 species.

Whether it is an actress trying to authenticate her Cornish accent, a documentary programme maker seeking out the sounds of a Costa Rican rainforest, or a composer drawing inspiration from an obscure field of ethnic folk music, the archive often holds the key.

There is, of course, a mass of curios—1930s music hall artists on flexi-discs

advertising BP Plus motor oil; 1960s Beatles sound-alikes promoting the possibilities of working as a Post Office telephone exchange operator; a 1903 recording of a geisha-girl brass band playing the Japanese national anthem; and Christabel, the daughter of Emmeline Pankhurst, the British women's rights pioneer, insisting on a militant struggle for women's suffrage after her release from London's Holloway Prison in 1909.

Century of listening

An extensive reference library complements the listening and viewing service with a wide range of catalogues, discographies, periodicals and monographs covering every aspect of recorded sound. Anyone tracing a particular recording will find the library invaluable in research as well as fascinating in its own right.

This year, the archive is celebrating 100 years of the invention of the gramophone with an exhibition called *Revolutions in Sound* that traces its development from children's toy machines to today's disc players.

The NSA collections are available for any member of the public to consult free of charge, but an appointment has to be made to listen to something special.

It was recently estimated that it would take over a century of non-stop listening to hear everything in the archive's collections—that is an indication of the incredible range of sound artefacts available.

RESTORING THE CLASSICS

Our inheritance of rare sound recordings on film, disc and wax cylinder is often painfully marred by a background of scratches, crackles and whistles.

This new system, developed by the British Library National Sound Archive in London, can produce major improvements in audio quality at a fraction of the cost of today's digital audio control desks. Known as CEDAR (Computer Enhanced Digital Audio Restoration), it is a low-cost digital signal processing hardware and software package and is compatible with standard desk-top computers.

CEDAR, it is claimed, is able to perform all the tasks of the latest digital processors, and to go beyond them in eliminating the sounds of scratches and crackle produced by wear and tear which have previously been impossible to mask successfully. By operating out of real time, a three-minute 78 rpm disc treated to reduce severe surface noise is easily handled overnight; once programmed the system operates automatically. Dramatic improvements to the quality of film sound-track or discs can be achieved.

The system includes programmes emulating features of signal processors, such as a spectrum analyser able to display a section of sound on the computer screen, as shown in the picture. It also has a filter capable of removing not only the pure tones of a mains hum but impure tones like heterodyne whistles. A special advantage of the equipment, however, is that, for the first time, it provides a satisfactory means of filling the gap left when a click or scratch has been removed. This is done by putting "white noise" through a filter that had been designed by the system to match the characteristics of the sound either side of the gap. This facility is particularly useful for maintaining music tempos and for film synchronisation.

CEDAR has been developed by the British Library National Sound Archive in collaboration with the Engineering Department of Cambridge University and Cambridge Electronic Design.

NEWS

Talking Newspaper on the move

QTI-TNA, The Talking Newspaper for blind radio amateurs, has moved to a new base in Lancaster, where it will be run by Harry Longley, GOJKT, with the help of students from the University of Lancaster.

The service provides readings of technical items selected from current radio magazines to more than 120 blind radio amateurs worldwide on a fortnightly basis.

Support from radio amateurs in the Lancaster area will be very welcome, and further help with funding will be greatly appreciated. All these should be addressed to H. Longley • QTI-TNA • 7 Anderson Close • LANCASTER LA1 3JE.

Racal CAD for Alcatel

Belgium's Alcatel NV, the world's second largest telecommunications manufacturer, is to standardize on Racal's *Visula* CAD system for its printed-circuit boards.

With this contract, Alcatel joins a host of international companies that have chosen Racal's CAD system. They include McDonnell Douglas, Hughes Aircraft, Thomson-CSF, Fujitsu, Nippon Telephone and Telegraph, Philips, Siemens, and Plessey.

Racal-Redac • TEWKESBURY GL20 8HE.

Electrovalue-Iskra agreement

Iskra has appointed Electrovalue a distributor of its range of surface-mount resistors and potentiometers.

Iskra Ltd • Redlands • COULSDON CR3 2HT

BT consortium's success with MoD contract

A consortium of information technology specialists led by British Telecom is one of two suppliers chosen by the Ministry of Defence for the next phase of its multi-million pound office automation system.

Known as the Corporate Headquarters Office Technology System (CHOTS), the system will be installed during the 1990s and will eventually serve 24,000 users in more than 40 MoD buildings throughout the UK.

Other members of the consortium are Secure Information Systems, Honeywell Bull, and Nixdorf Computer.

British Telecom • 81 Newgate Street • LONDON EC1A 7AJ.

A DISH FOR EUROPE

Although competition between the BSB and Astra satellite is hotting up and offers many interesting points of debate, it is unwise to speculate and anticipate before the first signals are beamed down. Astra has the advantage of the earlier launch, scheduled for this month. This article discusses the technical specification of the dish aerial developed by STS for reception of Astra, the 16-channel medium-power television satellite whose footprint is claimed to cover most of Western Europe.

The dish aerial designed by STS is a low-cost, 65-cm aperture off-set type which is claimed to deliver CCIR grade-4 quality signals in areas with 50 dBW EIRP coverage, and CCIR grade-3 quality signals in areas with 49 dBW EIRP coverage (CCIR grade-4 is defined as 'good'; grade-3 as 'fair', or roughly equivalent to a good-quality VCR). The 49 and 50 dBW areas house over 90% of the European population. The profiling and sizing of the aerial have been calculated to allow the use of low-cost LNBs with noise figures up to 2.2 dB ($T_r \approx 200$ K) in the centre of Astra's footprint, without degrading performance.

The STS dish can be deployed throughout Europe:

■ **Areas within 52 dBW contour:**
LNB noise figure 1.9 dB; $C/N \geq 13$ dB = CCIR grade-4.
France, Belgium, Netherlands, Luxembourg, West Germany, East Germany, Denmark, Switzerland, Austria, Eastern Poland, Northern Italy, England and wales, Northern Ireland, Western half of Eire.

■ **Areas within 50 dBW contour:**
LNB noise figure 1.5 dB; $C/N \geq 12$ dB = CCIR grade-3.
Scotland, Southern Scandinavia (Stavanger–Oslo–Stockholm), Central Poland, parts of Czechoslovakia, Hungary, Yugoslavia, Eire, Northern Spain.

Physical properties

The STS aerial is a compact and lightweight unit that comes complete with a simple-to-adjust azimuth-elevation adjustment.

Type:	offset focus; AZ/EL mount.
Aperture:	65 cm.
Dimensions:	65 cm (W) × 71 cm (H); elliptical.
Material:	aluminium.
Finish:	anodised, self-coloured.
Production method:	stamping.
Fiting options:	chimney, wall and corner.

Downlink budget and performance indicators

The chart in Fig. 1 shows results produced in terms of Astra EIRP against LNB noise figure to obtain a given C/N ratio. Bearing in mind that most current, individual, satellite TV reception is working on C/N figures around 8 or 9 dB, i.e., around or just above the FM demodulation threshold, results for ratios 10 and 11 are of particular interest. It is assumed that the STS dish will be used with satellite TV receivers capable of processing the full 26 MHz bandwidth, and having a demodulation threshold of 8 dB C/N, i.e., not low-threshold receivers working on smaller bandwidths which cause degradation of the picture quality.

The difference between the C/N ratios shown for the dish, and the assumed 8 dB threshold for receivers is the allowance for bad weather and other adverse conditions which cause additional attenuation of the satellite signal at 11.5 GHz. A C/N ratio of 13 dB at the dish means that picture quality will only be adversely affected 0.1% of the time. This is a huge improvement on current experience with low-power satellites.

Performance indicators:

Efficiency:	70%.
Gain:	36 dB minimum.
Beamwidth:	2.2° at −3 dB.

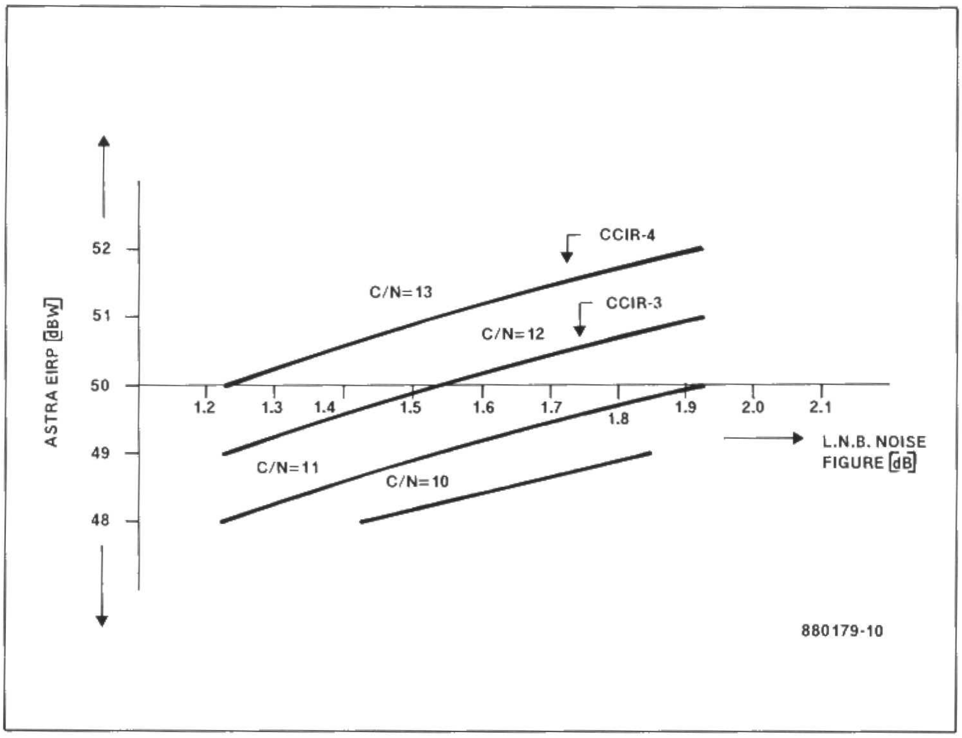


Fig. 1. Correlation between Astra EIRP and LNB noise figure with 4 C/N ratios as parameters.

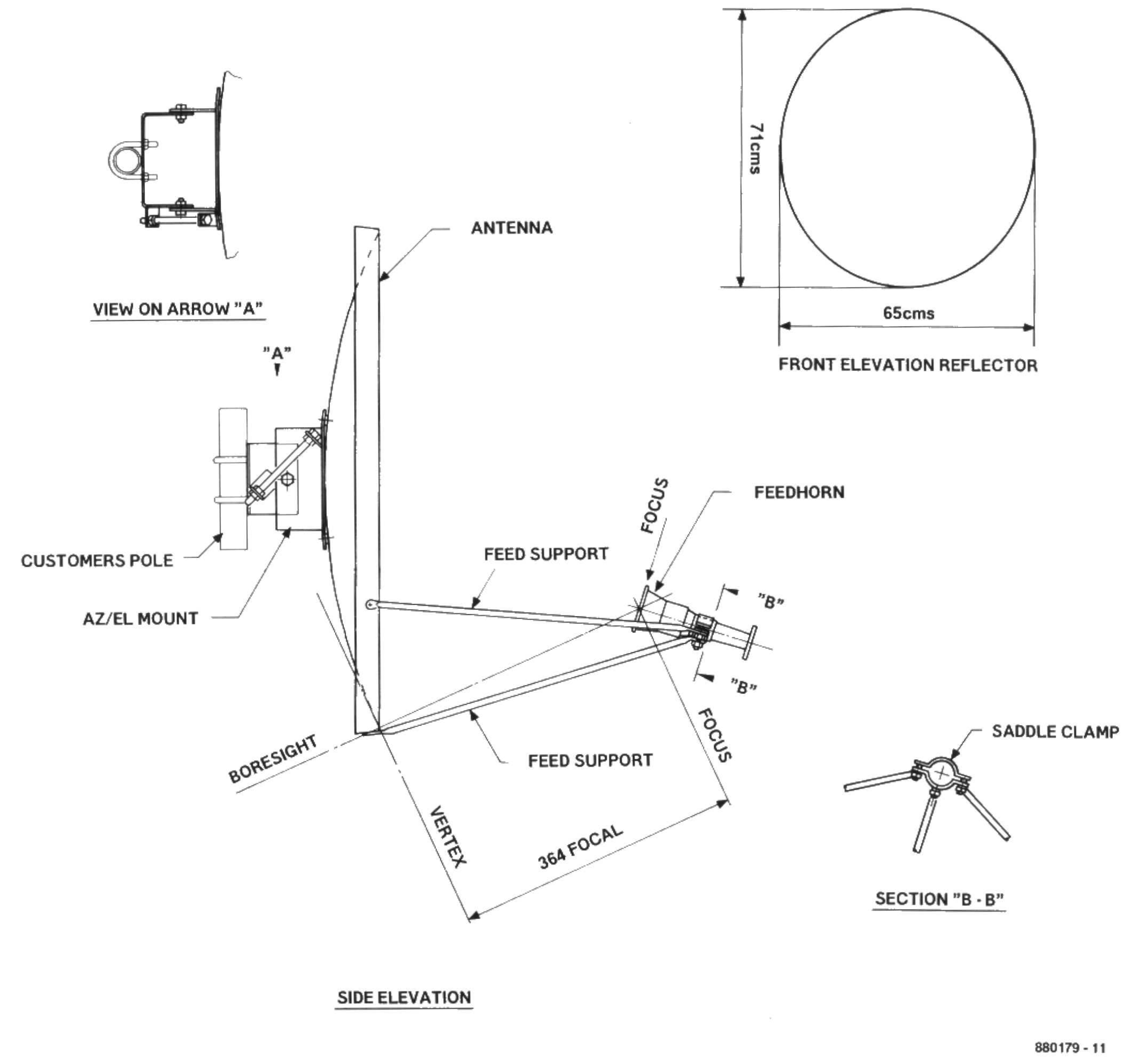


Fig. 2. Basic layout of the 65-cm dish supplied by STS.

The quoted dish gain is calculated from

$$G = 10\log \left[E\frac{4\pi A}{W^2} \right]$$

where
A = aperture area;
E = efficiency.
With $A = 3318$ cm^2, $\lambda = 2.677$ cm (11.2 GHz) and $E = 70\%$, the gain, G, works out at $10\log(4073) = 36.09$ dB.

The chart in Fig. 1 can be verified by calculating the C/N ratio from

$$C/N = (EIRP - L + G) - 10\log(TkBW) \text{ [dB]}$$

where
EIRP = effective isotropic radiated power from satellite (approx. 50 dBW);
L = path loss over approx. 37.000 km at 11 GHz (205.2 dB);
G = aerial gain (36 dB);
T = noise temperature of dish and LNB (LNB noise temperature: 101 K for 1.3 dB type, 170 K for 2.0 dB type; dish noise temperature: 50 K);
k = Boltzman's constant, 1.381×10^{-23}
BW = receiver bandwidth, 26 MHz (26×10^6 Hz).

Production of the dish is due to commence next month. It is supplied complete with a feed support, AZ/EL mounting, and standard fixings supplied individually protected and packed in outers of 50 or 100.
For details on specification, prices and availability, contact

STS Limited
Satellite House
Blackswarth Road
BRISTOL BS5 8AU.
Telephone: (0272) 554535.
Telex: 449752.
Fax: (0272) 745365.

BUS INTERFACE FOR HIGH-RESOLUTION LIQUID CRYSTAL SCREENS

Part 1

Although large LC display modules are currently available in many shapes and sizes, their special serial input calls for the use of an interface to enable connection to a computer bus. The interface described here is versatile, yet relatively simple to configure and program as a bus-connected device in a number of popular computer systems. Although the application discussed concentrates mainly on the 400×64 dot matrix LCD module Type LM40001 from Sharp, the interface board is also suitable for a number of similar units in Hitachi's LM series.

Liquid crystal display (LCD) units for text and graphics applications are usually supplied as a module consisting of a glass-protected, reflective backplane (the actual display), and a controller board attached to it at the rear side. The controller translates the data applied to its serial input into backplane waveforms, which result in dot patterns that form legible characters or graphic shapes. In most cases, LC controllers have an on-board character ROM. The serial format used for controlling LC display modules is usually of a type that bears no resemblance whatsoever to that adopted for, say, the well-known RS232 port. When a large, intelligent LC display module, such as the LM40001, is to be used in conjunction with a computer, an interface circuit is required as described in this article.

Among the computers that can be connected to the present interface are
- 6502-based systems (C64, C128, Acorn computers);
- Z80-based systems (CP/M and MSX computers);
- IBM PCs and compatibles;
- the *Elektor Electronics* BASIC computer [1].

Significantly, the LCD interface can be controlled entirely in BASIC.

Liquid crystal screens

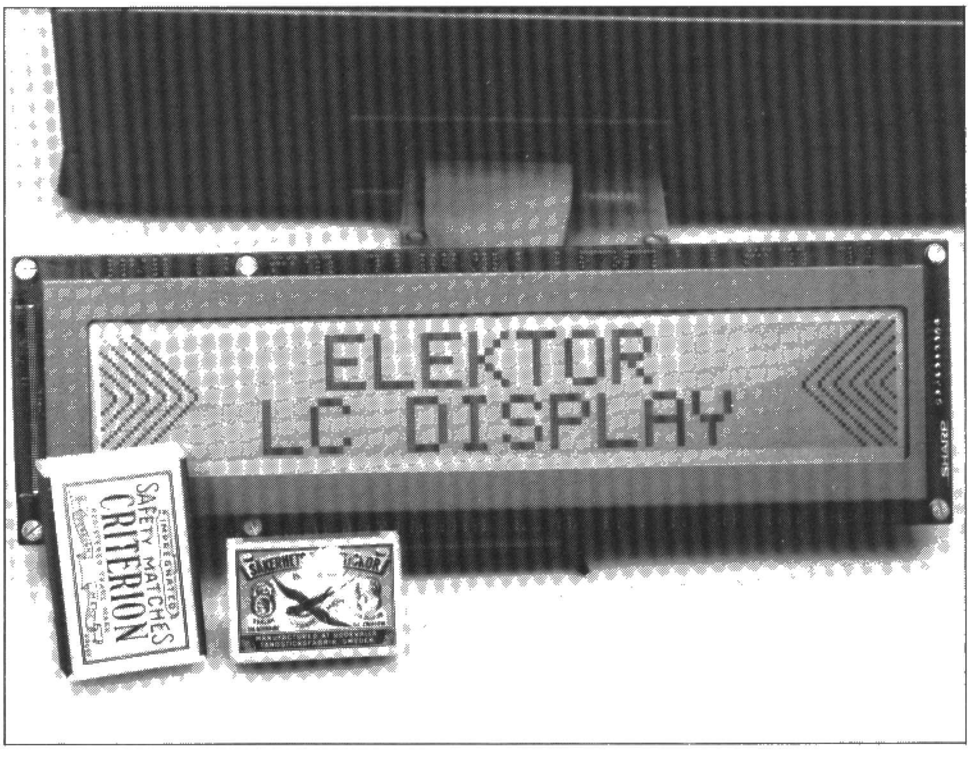
Although Sharp's Type LM40001 is, strictly speaking, a liquid crystal display module, it is better qualified as a *liquid crystal screen* because of its large viewable area (220×35 mm), and its ability to process data as graphics information (individual dots can be addressed). This is in contrast to most smaller LCD units, which are usually only capable of displaying text and numbers on 1, 2 or sometimes 4 lines, depending on the size.

An LC screen is essentially a dot-matrix display unit without predefined characters. The interface described here, in conjunction with the existing backplane controller on the LC screen module, makes it possible to combine dot patterns into legible characters, just as on a TV screen, or a dot-matrix printer.

Although the prototype of the interface was developed, tested and used in conjunction with the LM40001 from Sharp, it can also be connected direct to Hitachi's Types LM200, LM021, LM212 and LM211. These, and similar units from other manufacturers, are occasionally offered inexpensively at rallies and in surplus stores (but make sure you obtain the relevant data sheets).

Principle of operation

The block diagram of Fig. 1 shows that an address decoder is required to 'map' the LC screen in the computer's memory. Depending on the type of processor in the computer, this address can be in actual memory (e.g., 6502-based



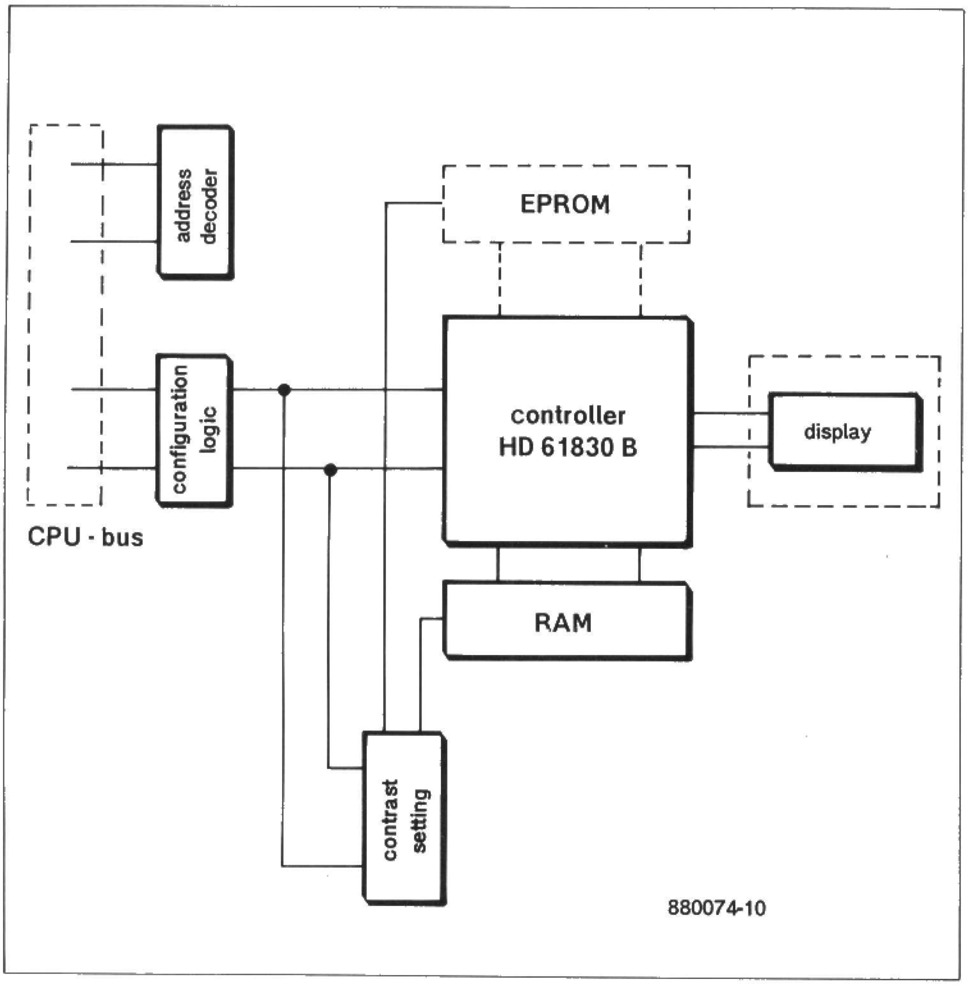


Fig. 1. Block diagram of the universal LC screen interface.

systems), or in the I/O segment (e.g., Z80-based systems). The configuration logic, shown as a separate block in Fig. 1, is required to ensure correct timing and combination of the pulses for the interface.

The 8 Kbyte RAM block is divided in two 4 Kbyte segments by a dedicated LCD controller chip, the Type HD61830B from Hitachi. In text mode, each 4 Kbyte screen memory holds the data for ten text windows. In graphics mode, the same memory holds one graphics screen. The difference in storage capacity between the text mode and the graphics mode is brought about by the fact that any ASCII character (a complex dot pattern) can be called up by only one byte, whereas, in graphics mode, that same single byte produces only a horizontal row of 8 dots.

The internal division of the screen memory in displayable windows is shown in Fig. 2. An external control signal provided by a latch divides the memory in two equal halves. The start address determines which 400 memory locations appear on screen ('display window'). Hence, there are 10 text screens (4096/400). The on-screen location of the next character loaded is determined by the cursor address, which is automatically incremented by one after the controller has displayed the current character.

Starting at cursor address 0, and assuming that the start address is not changed, characters following number 400 will not be displayed, but are still loaded in the screen momory. They become visible only when the start address is moved up accordingly ('scrolling'). Old data then disappears from the screen, but remains in the screen memory. Memory location 0 is overwritten, however, with new data

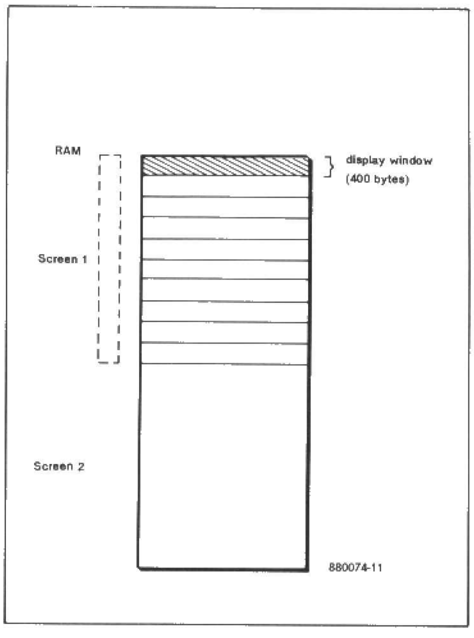


Fig. 2. Each screen memory of 4 Kbytes is subdivided in ten windows of 400 bytes.

when the screen memory is full. Scrolling per line or per screen is simple to effect by incrementing the cursor start address in steps of 8 or 50, respectively, assuming that the LC screen is programmed to display 8 lines of 50 characters.

In graphics mode, 50 bytes are required for 400 dots horizontally. The vertical resolution is 64 dots, so that one graphics screen corresponds to 50×64=3200 bytes. This means that the screen memory (4 Kbyte) can hold one graphics screen with 896 bytes left.

The controller used in the interface circuit is a relatively complex chip. It has a built-in character ROM, and takes care of the parallel-to-serial conversion of the data provided by the computer interface circuit. When an (optional) external EPROM is added, the user has a choice of three character fonts.

The last block in Fig. 1 is the contrast control circuit. A discrete 4-bit DAC is driven via a register, and provides a 16-level contrast setting. The directly addressable register is also used for switching between the two 4 Kbyte screen memories, and the two EPROM-resident fonts, which are optional.

Circuit description

The complexity of the circuit shown in Fig. 3 is only apparent, and caused mainly by the ability of the interface to be driven by various types of computer. Connector K_1 links the computer's CPU to the LC screen interface. Circuits IC_6 and IC_7, together with 8-way DIL switch blocks, form a presettable 16-bit address decoder for mapping the card in the computer's memory. When the bit pattern set by means of the DIL switches matches that on the address bus, output $\overline{P=Q}$ goes low. The least significant three address lines are not connected to the address decoder, and appear as X0, X1 and X2 on the internal bus of the interface. This arrangement allows the combining of system-dependent signals with the address decoding. In the case of the IBM PC, for instance, X0 carries signal AEN. Similarly, with MSX systems, X2 carries $\overline{IOREQ}$, and X0 bus signal M1 (X1 is not used, jumper R is not fitted). The interface occupies 8 memory locations, 5 of which are used for addressing registers — see Table 1. Circuit IC_5 functions as a bidirectional databus buffer. Together with IC_3, a decoder for internal signals, it is enabled when the interface is selected via the computer's address bus. Gates N_1 to N_6 convert and combine the control signals provided by the microprocessor bus. Table 2 provides bus connection information, and lists the configuration of jumpers A to T, in accordance with the computer system used.

Interface output $\overline{WAIT}$ is provided to

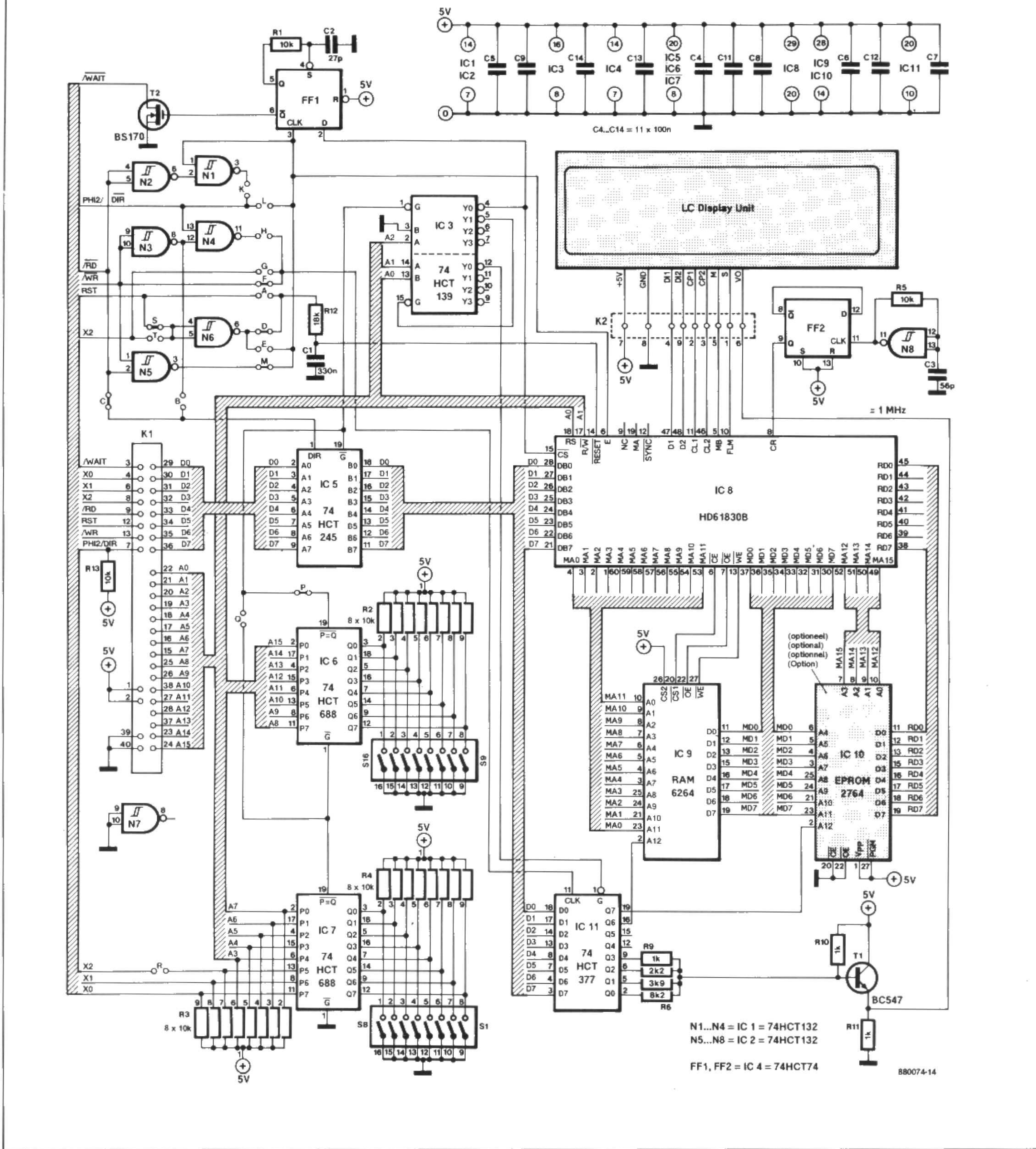


Fig. 3. Circuit diagram of the universal interface for high-resolution liquid crystal screens. The configuration of the jumpers is in accordance with the type of computer used for driving the circuit.

ensure correct operation of the controller when this is connected to a relatively 'fast' computer bus. Bistable FF_1 is a monostable multivibrator which pulls $\overline{WAIT}$ low via FET T_2. Its monotime is about 450 ns, as set with network R_1-C_2. $\overline{WAIT}$ is an open-drain line that can be connected to an existing wired-AND network as used in IBM PCs (8088/8086) and MSX micros (Z80). Obviously, $\overline{WAIT}$ is not used in systems where it is not required.

The $\overline{RESET}$ input of the controller, IC_8, is connected to the CPU $\overline{RESET}$ line via a low-pass filter, R_{12}-C_1, which serves to suppress spurious pulses.

Circuit IC_{11} is the previously discussed latch for the contrast setting circuit. Its outputs, Q0 to Q3, drive the discrete DAC, R_6-R_9-T_1. Only two of the remaining four outputs of IC_{11} are used — Q6 and Q7 as the RAM as the 4 Kbyte selection lines, A12, of the screen RAM (IC_9) and character EPROM (IC_{10}) respectively. It is possible to store 4 screen fonts in EPROM by using the 16 Kbyte 27128, and one of the two remaining

outputs on IC_{11} as the 14th address line. The clock generator for the controller chip is formed by an R-C oscillator, N_8. The actual clock frequency is not so important, but a symmetrical clock signal is a must for the HD61830B, hence the use of divide-by-two bistable FF_2.

One slightly unusual connection in the interface circuit is that of input R/−W of the controller to address line A_1. This solution was adopted to solve possible timing problems. Read and write levels should be available 140 ns before the enable pulse, which, in turn, should have a minimum duration of 440 ns. The connection of A1 to R/−W results in different addresses for read and write operations to the interface registers — see Table 1.

Table 1. Data/Control Registers

Address	A15 A3	A2	A1	A0
DATA-WR	x	0	0	0
CTRL-WR	x	0	0	1
DATA-RD	x	0	1	0
CTRL-RD	x	0	1	1
LATCH	x	1	0	0

Construction

The LC screen interface is constructed on a double-sided, through-plated printed circuit board (see Fig. 4). The track layout is not given here because this PCB is virtually impossible to make other than from films, while through-plating equipment is usually only available in a professional workshop. The size of the ready-made PCB is such that it can be attached to the controller board of the LM40001 unit with the aid of 4 spacers.

To be continued next month.

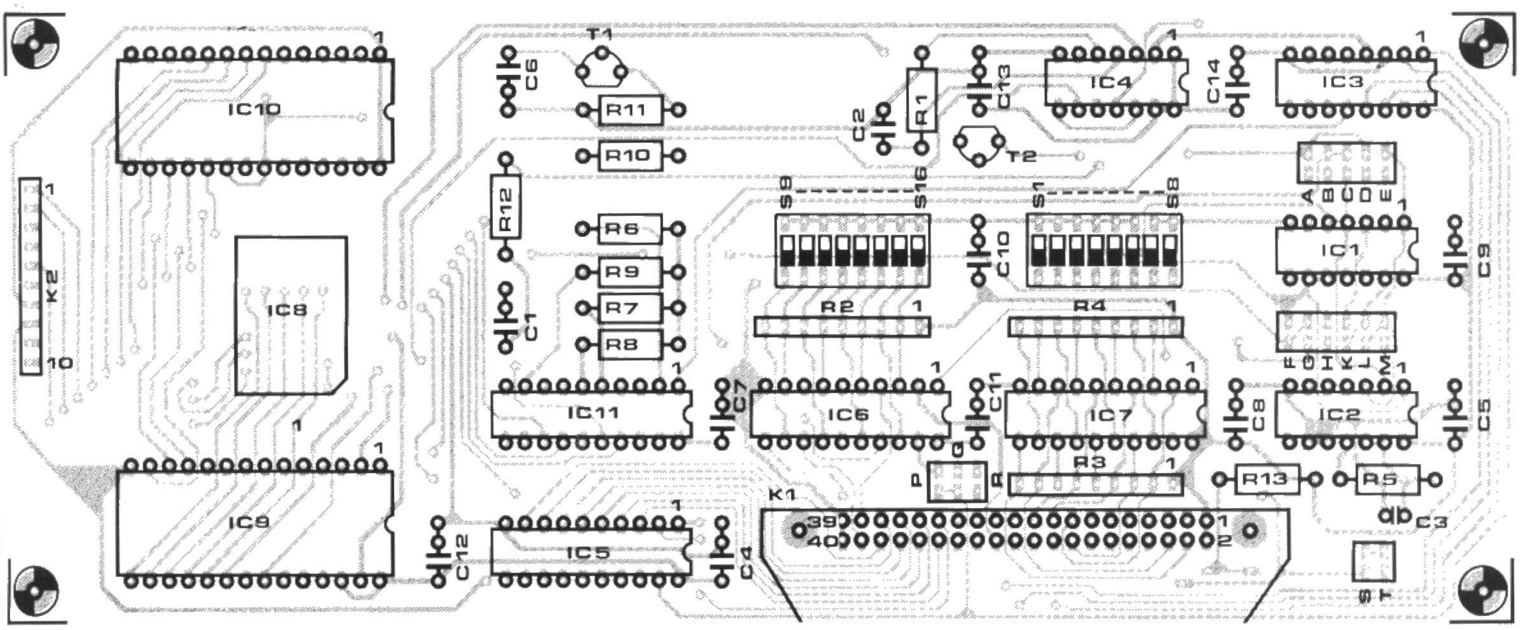


Fig. 4. Component mounting plan of the double-sided, through-plated PCB for the LC screen interface. This high-quality PCB is available ready-made through the Readers Services.

Parts list

Resistors (±5%):

R_1;R_5;R_{13} = 10K
R_2;R_3;R_4 = SIL resistor array 8 × 10K
R_6 = 8K2
R_7 = 3K9
R_8 = 2K2
R_9;R_{10};R_{11} = 1K0
R_{12} = 18K

Capacitors:

C_1 = 330n
C_2 = 27p
C_3 = 56p
C_4 . . . C_{14} incl. = 100n

Semiconductors:

T_1 = BC547B
T_2 = BS170
IC_1;IC_2 = 74HCT132
IC_3 = 74CT139
IC_4 = 74HCT74
IC_5 = 74HCT245
IC_6;IC_7 = 74HCT688
IC_8 = HD61830B (Hitachi)*
IC_9 = 6264 or 8264 8K × 8 static RAM
IC_{10} = 2764 (optional character set EPROM, available as order number ESS 560 through the Readers Services).
IC_{11} = 74HCT377

Miscellaneous:

S_1 . . . S_8 incl.;S_9 . . . S_{16} incl. = 8-way DIL switch block.
K_1 = 40-way PCB header with eject handles; male; with angled pins for PCB mounting.
K_2 = 10-way SIL header.
PCB Type 880074 (see Readers Services page).
LC display Type LM40001 (Sharp Electronics)*.

* Listed by C-I Electronics (see advertisement in July/August issue, p. 69).

Hitachi Electronic Components (UK) Ltd. • Hitec House 221-225 Station Road • Harrow • Middlesex HA1 2XL. Tel.: (01 861) 1414. Tlx.: 936293 hitec g. Fax: (01 863) 6646.
Hitachi distributors in the UK are listed on InfoCard 504 (*Elektor Electronics* March 1987).
Hitachi Electronic Components Europe GmbH (Headquarters). • Hans-Pinsel Strasse 10A • D-8013 Haar nr. Munich. Tel.: +49 894614/0. Tlx.:5-22593 hitc d. Fax: +49 89463151.

Sharp Electronics (UK) Ltd. • Sharp House • Thorp Road • MANCHESTER M10 9BE. Tel. (061 205) 2333. Fax: 061 205 7076.

SIMPLIFIED TIME-SIGNAL RECEIVER

The automatic synchronization facility of many microprocessor-based clocks ensures reasonable long-term accuracy even when the relevant time-signal transmitter is received for only a couple of minutes each day. Obviously, this feature relaxes the design requirements of the receiver, which can be kept relatively simple. Such a receiver is described here: it has a digital pulse output, excellent sensitivity, and can be tuned to time-standard stations transmitting in the VLF band between 50 and about 100 kHz.

Time-signal transmitters such as Rugby MSF, HBF and DCF77 operate in the VLF (very low frequency) band, at frequencies between 50 and 100 kHz. The VLF band is characterized by very predictable propagation characteristics, but received signals often suffer from interference generated by electrical apparatus such as TV sets and dimmers. The receiver should, therefore, have good or very good selectivity. The frequency conversion principle (heterodyne receiver) must be dismissed, however, when the practical design is to remain as simple as possible.

Circuit description

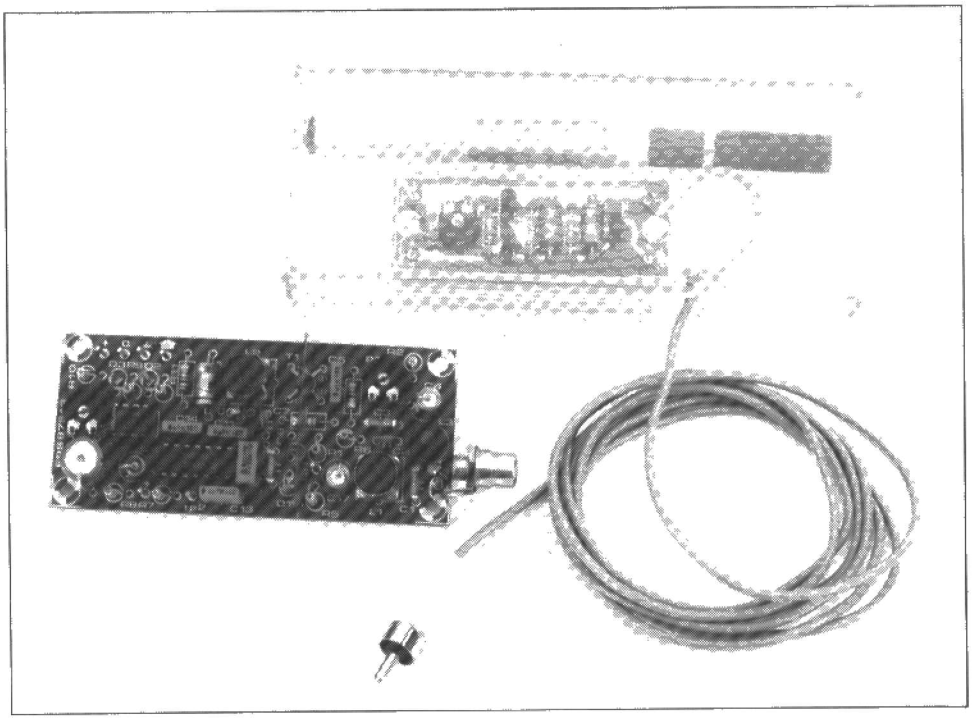
Selectivity of the present VLF receiver is determined solely by the aerial and two tuned circuits. High-gain RF amplifiers are used, and a special, non-linear, demodulator extracts the time signals from the still relatively noisy RF input signal.

The circuit diagram of Fig. 1 shows that the RF signal from the transmitter is picked up by an active aerial circuit, whose output signal is filtered by tuned circuit L_1-C_2, and amplified by dual-gate MOSFET T_1. A further tuned circuit inserted in the drain line of this transistor ensures adequate receiver selectivity. The drain signal is rectified by D_1 to provide automatic gain control (AGC) on gate 1 of the MOSFET. The AGC has a relatively slow response because fading is generally slow on VLF.

Circuit IC_1 is a Type SO42P balanced mixer/oscillator from Siemens. In the present application, it functions as a four-quadrant multiplier, so that its output signal is proportional to the square of the input signal provided by T_1. The modulation frequency on DCF77 is relatively low, so that a single R-C network, R_8-C_{15}, is sufficient for removing the RF component from the rectified time signals. These are filtered and shaped in a further (active) rectifier, IC_{2a}, whose output signal is a measure of the instantaneous amplitude of the time signals. The discharge time of C_{16} is relatively long (P_2-R_{10}), so that the voltage on this capacitor is largely constant for the duration of the time pulses. Comparator IC_{2b} compares the instantaneous amplitude of the rectified voltage to a part of the absolute amplitude, set with P_2.

The output of the receiver supplies time pulses as they are modulated, i.e., a time pulse corresponds to a logic low level. This makes the present time signal receiver compatible with the Intelligent Time Standard published in Ref. [2], but only if DCF77 is being received.

The circuit diagram shows the capacitor values needed for reception of DCF77 on 77.5 kHz. The tuned circuits can be modified for reception of, for instance, Rugby MSF at 60 kHz, by multiplying the value of C_2, C_7 and C_8 by a factor $(77.5/60)^2 \approx 1.67$, and using the closest practical capacitor value.



Completed prototype of the simplified time signal receiver, connected to the associated active aerial.

Construction and alignment

The receiver is composed of two boards: active aerial and receiver/demodulator. The active aerial is identical to that used for the DCF77 receiver and locked frequency standard (see Ref. [1]). The unit is constructed on the small printed circuit board shown in Fig. 2. The aerial, L_5, is formed by about 200 closewound turns of 0.2 mm dia. enamelled copper wire on a 30 mm long cardboard or paxolin former. This is slid on to a 12-20 cm long ferrite rod of 10 mm diameter. The rod and associated former used for building the prototype receiver were parts salvaged from a discarded MW/LW radio.

Populating the receiver/demodulator board shown in Fig. 3 should not present problems. A 15 mm high tin plate or brass screen is fitted across T_1 as shown

on the component overlay. The screen has small clearances for T_1 and R_3, and is secured to the PCB with the aid of two soldering terminals. Note that a number of parts are fitted upright.

Use one metre or so of screened microphone wire to connect the active aerial to the main receiver board.

First, concentrate on setting up the active aerial. Power up and check the DC settings at the points indicated in the circuit diagram. Set a sine-wave generator to the receiving frequency (e.g., 77.5 kHz), and connect a coupling loop and a series resistor to the output of the instrument. Wind the coupling loop on to the ferrite rod, and connect an AC-coupled oscilloscope to the output of the active aerial. Slide the former until the signal amplitude is a maximum. Reduce the output of the generator, and move the coupling loop away from the rod.

Again slide the former on the rod to find the resonance point. If this is found with the former partially off the rod, the number of turns of L_5 should be reduced. Experiment with the value of C_{44} and the setting of P_2 until the completed active aerial has a selectivity of about 10 kHz, and the former is about flush on the rod. When this cannot be achieved, the ferrite rod may have incorrect RF properties, and there is no alternative but to try out another type. After adjustment, the former is secured on the ferrite rod by means of wax or sellotape. Do not use a metal support for fixing the rod.

Switch off the generator, increase the sensitivity of the scope, and rotate the rod in the horizontal plane until the RF signal from the time signal station is observed on the oscilloscope screen. The signal is relatively small, but should have an amplitude between 5 and 50 mV_{pp}. Connect the probe to the drain of T_1, and carefully peak L_1 and L_2 for maximum amplitude. If clipping or oscillation occurs, reduce the gain of T_1 by adjusting P_1. Readjust the active aerial and the tuned circuits with a high-impedance voltmeter connected to pin 2 of IC_1.

The time signals can be heard on high-impedance (600 Ω) headphones connected between the positive supply and test point TP2. Finally, mount the active aerial in a position well away from

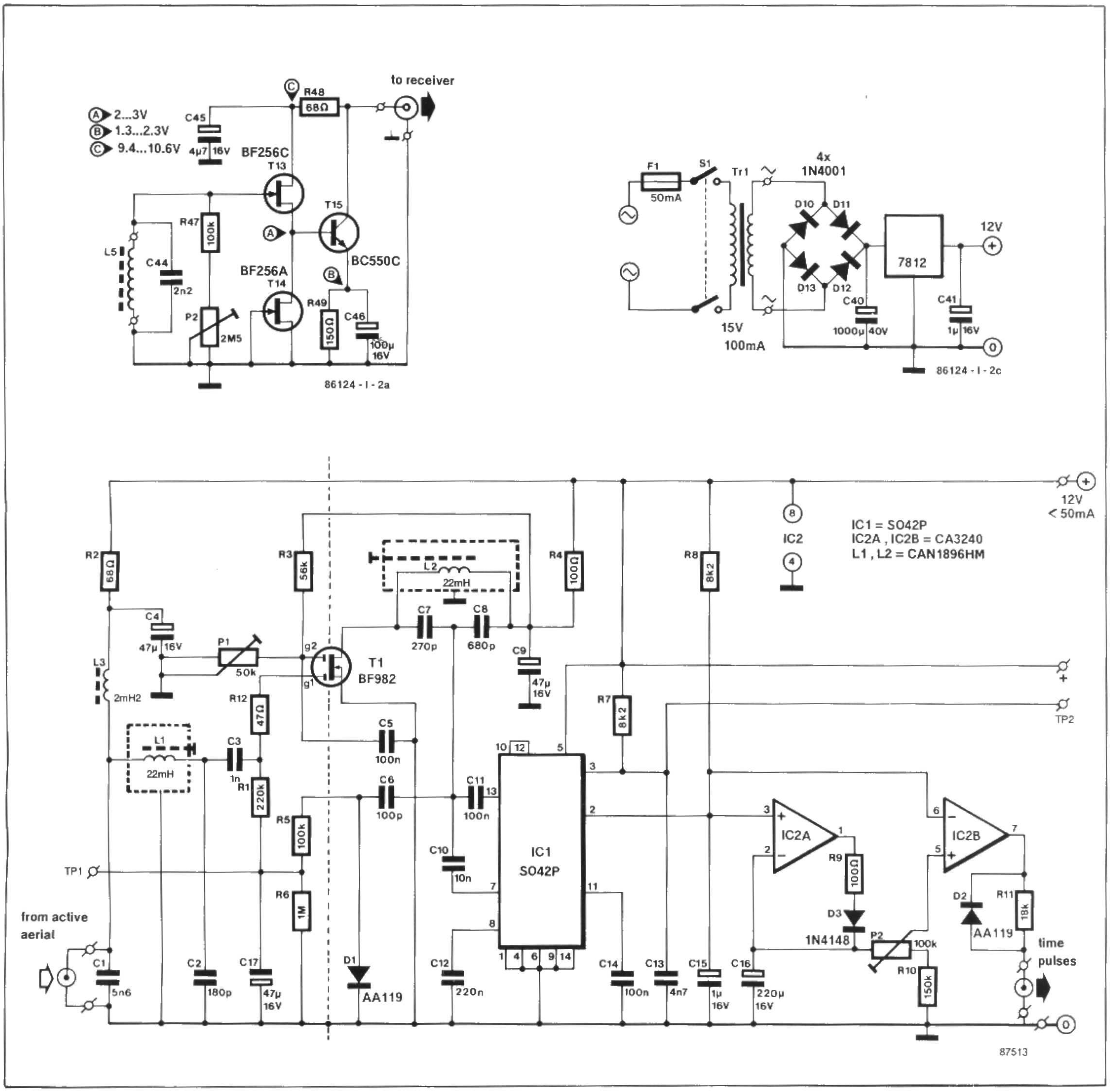


Fig. 1. Circuit diagram of the VLF time signal receiver.

sources of interference. The length of the screened cable between the active aerial and the main receiver board should not exceed 15 m or so.

References:
(1) DCF77 receiver and locked frequency standard. *Elektor Electronics* January 1988, p. 24-29.
(2) Intelligent time standard. *Elektor Electronics* February 1988, p. 22-30.

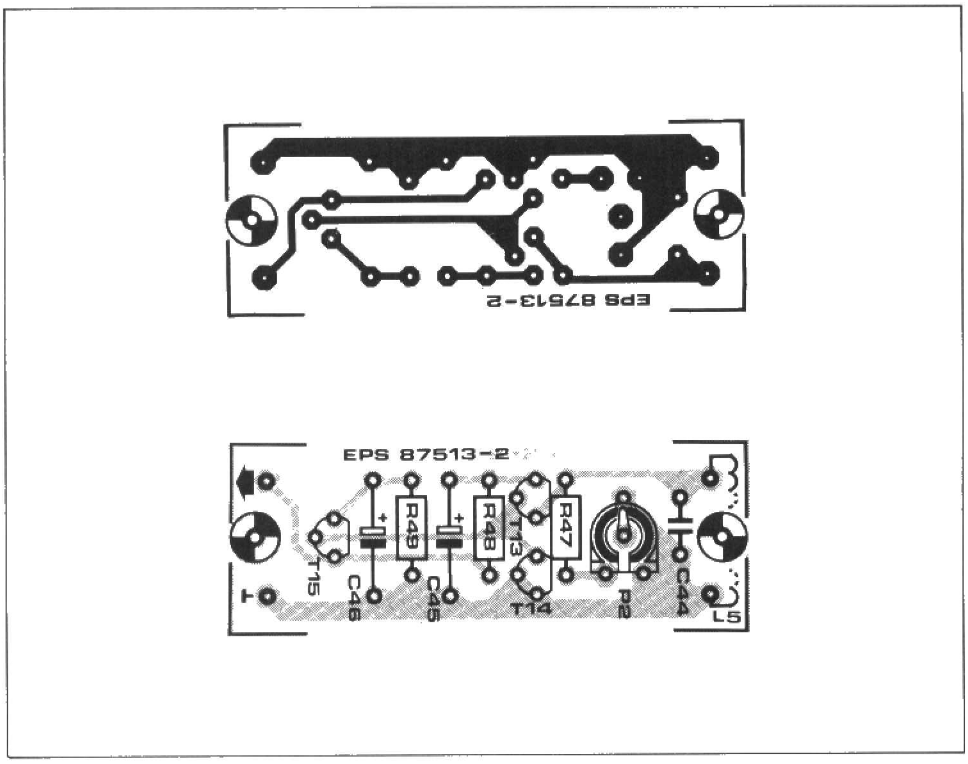


Fig. 2. Printed circuit board for the active aerial.

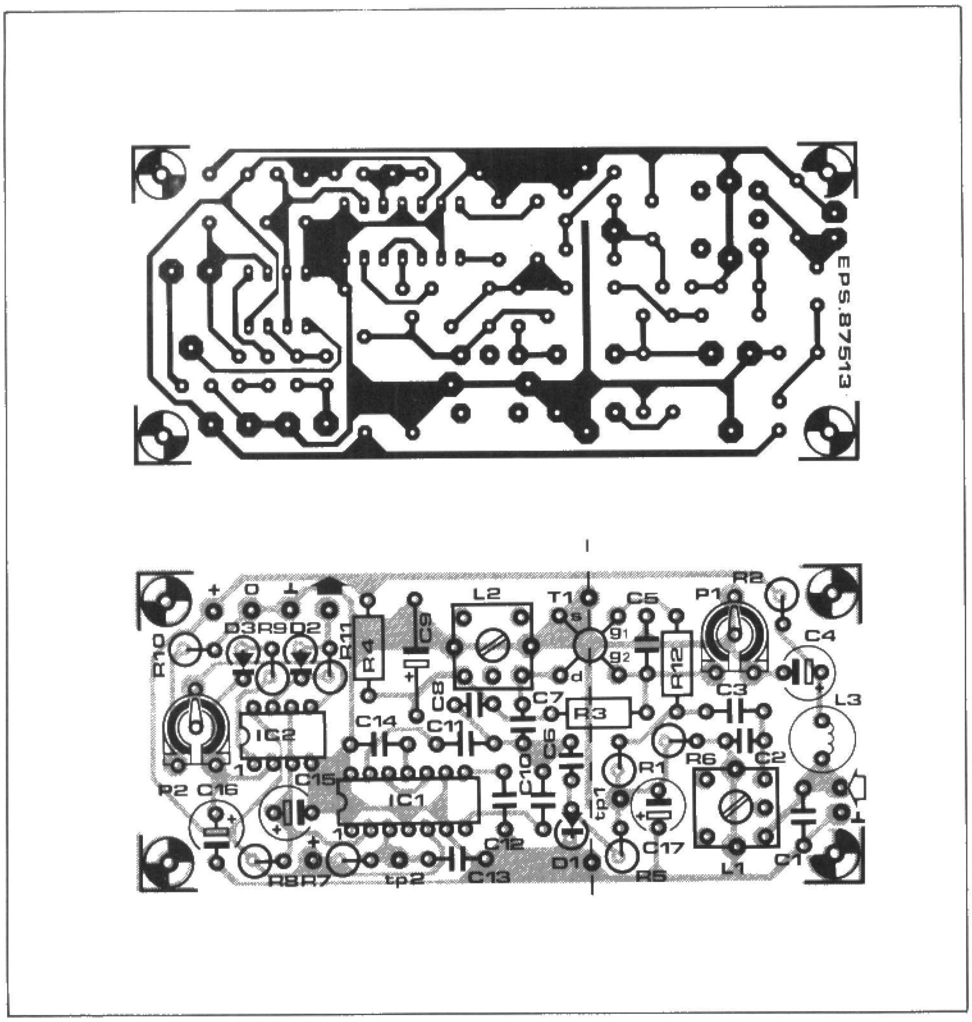


Fig. 3. Printed circuit board for the time signal receiver/demodulator.

Parts list

ACTIVE AERIAL:

Resistors (±5%):
R47 = 100K
R48 = 68R
R49 = 150R P2 = 2M5 preset H

Capacitors:
C44 = 2n2
C45 = 4μ7; 16 V; radial
C46 = 100μ; 16 V; radial

Semiconductors:
T13 = BF256C (Cricklewood)
T14 = BF256A (Cricklewood)
T15 = BC550C

Inductor:
L5 = see text. Ferrite rod: e.g. Cirkit Type FRA (stock number 35-14147).

Miscellaneous:
PCB Type 87513-2 (see Readers Services page).

MAIN RECEIVER BOARD:

Resistors (±5%):
R1 = 220K
R2 = 68R
R3 = 56K
R4;R9 = 100R
R5 = 100K
R6 = 1M0
R7;R8 = 8K2
R10 = 150K
R11 = 18K
R12 = 47R
P1 = 50K preset H
P2 = 100K preset H

Capacitors:
C1 = 5n6
C2 = 180p
C3 = 1n0
C4;C17 = 47μ; 16 V; radial
C5;C11;C14 = 100n
C6 = 100p
C7 = 270p
C8 = 680p
C9 = 47μ; 16 V; axial
C10 = 10n
C12 = 220n
C13 = 4n7
C15 = 1μ0; 16 V; radial
C16 = 220μ; 16 V; radial

Inductors:
L1;L2 = 22mH variable; Toko 10PA series, Type CAN1896HM (Cirkit stock number 35-18960).
L3 = 2mH2 radial choke; Toko Type 181LY-222 (Cirkit stock number 34-22202).

Semiconductors:
D1;D2 = AA119
D3 = 1N4148
T1 = BF982 (C-I Electronics)
IC1 = SO42P (Bonex; C-I Electronics; Universal Semiconductor Devices Ltd.)
IC2 = CA3240

Miscellaneous:
PCB Type 87513-1 (see Readers Services page).

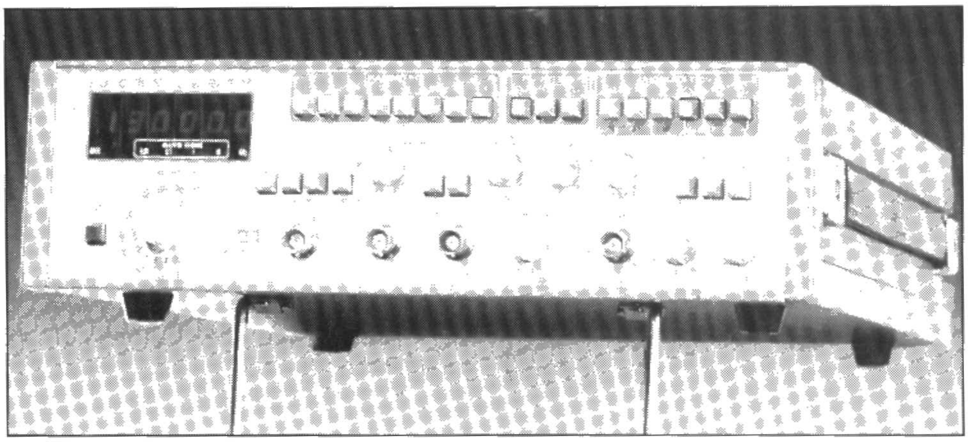
Note: PCB Types 87513-1 and 87513-2 are supplied as a set and cannot be ordered separately.

TEST & MEASURING EQUIPMENT

Part 11: AF Signal Generators (5)

by Julian Nolan

GE GFG-813 AF Signal Generator



Made by GW of Taiwan, the GFG-813 has a frequency range of 0.1 Hz to 13 MHz, a built-in digital frequency counter, and comprehensive modulation/sweep facilities. Its recommended retail price—RRP—is £795, excl VAT.

For an instrument in its class, the GFG-813 is relatively compact and lightweight. Its dimensions are 310×99×380 mm (W×H×D) and its weight is 5 kg.

The instrument may operate from 100-120-220-240 V 50 or 60 Hz a.c. mains supplies.

The instrument comes with a number of accessories, including three high-quality BNC-alligator connecting leads, IEC terminated mains lead, spare fuses, and an instruction manual.

The instrument is fitted with a single-position swivel stand, which allows the GFG-813 to be operated either at an angle or horizontally.

The appearance of the GFG-813 is dominated by the frequency counter, which is grouped with the main output controls. The modulation and sweep generator controls are laid out clearly in a separate section at the right of the generator.

Main generator. A single linear control sets the output frequency with the aid of the frequency counter, although rough gradations are also furnished. The output frequency can, therefore, be set very accurately, although the limitations of the resolution of the single rotary control, and of drift, should not be ignored. Fine and coarse controls for frequency setting, as provided on a number of other signal generators with a similar kind of frequency display, might have been useful.

The frequency range may be selected in eight decade ranges from 0.1 Hz to 13 MHz (the review model covered 0.05 Hz to 13.2 MHz). Symmetry may be adjusted over a range of 80:20 and 20:80 to 1 MHz.

The output level may be set up to 20 V_{pp} at the main output. Low-level performance of the GFG-813 is good. The −20 dB and −40 dB attenuators make accurate setting of low-level outputs an easy task. The maximum attenuation is −60 dB.

Noise levels at low-level outputs are good and compare well with those that may be expected from much dearer instruments.

Since a TTL output is not provided, it is just as well that an off-set control is provided. This omission is surprising, particularly in view of the other facilities, which include, for instance, a synchronization output with a non-adjustable level of 1 V_{pp}.

Triggering facilities are good; the external trigger input allows single or multiple cycles (burst mode), and trigger phase control. Overall, this operates well; the burst mode is particularly effective for measurements on a.f. equipment. Owing to the crowded front panel, the controls for external triggering are mounted on the rear panel, as is the VCF input.

A gate mode is also available.

Preset output waveforms are limited to the conventional sine, triangle, and square waves, although these may be modified, of course, by the symmetry control.

Output level flatness on sine wave is reasonable: $< \pm 3\%$ to 100 kHz and $< \pm 8\%$ to 13 MHz on the review model. Because of this, the output level may need adjusting if a fairly large frequency change is made.

Distortion is what may be expected: 0.5% from 10 Hz to 50 kHz and $>$ 33 dB below the fundamental to 13.2 MHz.

Linearity of the triangle output is good up to 3 MHz, after which some distortion becomes noticeable.

Square-wave symmetry and rise/fall times are also good, with the latter $<$ 18 ns on the main output.

Modulation generator. The modulation facilities and performance of the GFG-813 are excellent. Three modulation modes are available: FM, AM, and sweep. Modulation may be provided internally or externally. Internal functions are sine, square, and triangle. The symmetry of all three may be varied by the separate symmetry control.

Frequency setting is by three range switches and an uncalibrated, continuously variable control. These afford a frequency range of 0.1 Hz to 10 kHz (0.06 Hz to 11.3 kHz on the review model).

The modulating signal is available as an output, and may be used to drive the digital frequency counter. It may also serve as a separate function generator output. The level of this signal is variable to give modulation depths from zero to 100% on AM or from zero to ±5% on FM.

The performance of this secondary generator, in terms of distortion, linearity, and so on, is understandably not up to the standards of the main generator. Some users may find the THD figures of up to 2% at 10 kHz unacceptable for some applications.

Table 15

Main generator
Frequency range: 0.1 Hz to 13 MHz in 8 decade ranges.
Symmetry: 80:20:80 in 1 MHz.
D.C. off-set: ±10 V (no load); ±5 V (50 ohms).
Attenuator: −20 dB; −40 dB; −60 dB.
Output impedance: 50 ohms.
Output voltage: > 20 V_{pp} (no load): > 10 V_{pp} (into 50 ohms at 1 kHz).
Waveforms: sine, square, triangle, ±ramp, pulse, AM, FM, sweep, triggered and gated.
Sine wave: THD (10 Hz−50 kHz) < 0.5%; THD (50 kHz−13 MHz) > 30 dB below fundamental; flatness < ±3% from 10 Hz to 100 kHz and < ±10% from 100 kHz to 10 MHz.
Triangle wave: linearity < 1% at 100 kHz.
Square wave: symmetry < 2% from 0.1 Hz to 100 kHz; rise/fall time < 18 ns.

Modulation generator
Modes: AM, FM, sweep, trigger, gate or burst (int. and ext.).
Waveforms: sine, square, triangle with variable symmetry variations.
Frequency range: 0.01 Hz to 10 kHz.
Output voltage: > 1 V_{pp} in to 10 kilohms.
Sine wave: THD (10 Hz−10 kHz) < 2%.
AM: depth 0−100%; modulation frequency (int.) 0.01 Hz to 10 kHz, (ext.) d.c. to 1 MHz: external sensitivity < 10 V_{pp} for 100% modulation.
FM: deviation 0 to ±5% (int.); modulation frequency 0.01 Hz to 10 kHz (int.) or d.c. to 50 kHz (ext.).
Sweep: width > 100:1; rate 0,01 Hz to 10 kHz; ramp 90:10; ramp output 0 to > −4 V_{pp} into 5 kilohms.
Gate: start/stop; phase range +90° to −80°.
Frequency range: 0.1 Hz to 10 MHz.
External gate frequency: d.c. to 1 MHz TTL compatible.

Frequency counter
Int./Ext.: switch selectable.
Accuracy: ±10 p.p.m. (oscillator frequency 10 MHz).
Resolution: 0.1 Hz; 1 Hz; 10 Hz; 100 Hz; 1 kHz.
Frequency range: 0.1 Hz to 30 MHz.
Sensitivity: < 20 mV r.m.s.

Miscellaneous
Mains input: 100-120-200-240 V 50/60 Hz a.c.
Accessories: mains lead; 3 connecting leads; manual.
Dimensions: 310×99×380 mm (W×H×D).
Weight: 5 kg.

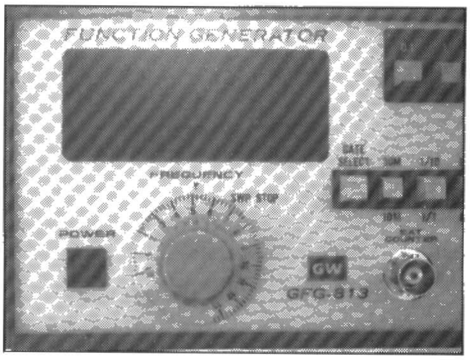
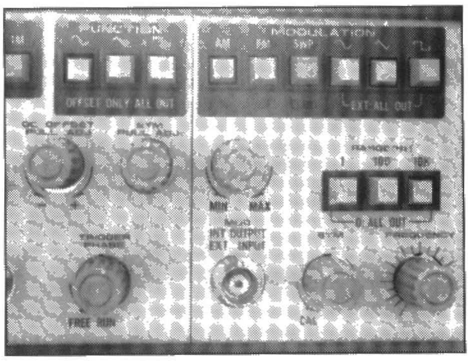
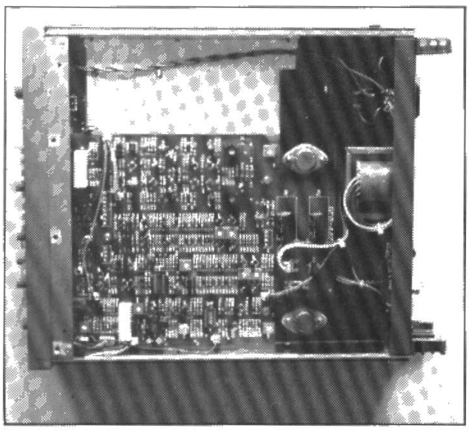


Table 16

	Unsatis-factory	Satis-factory	Good	Very good	Excellent
Dial accuracy					*
Dial resolution			*		
External sweep range			*		
Distortion			*		
Frequency range				*	
Output level range					*
Internal construction				*	
External construction				*	
Overall specification					*
Ease of use				*	
Manual				*	
Additional features				*	





None the less, this detracts little from the modulation generator's performance proper; if necessary, external modulation may be used.
In the external modulation mode, the modulation level control is still operative, and this allows for accurate setting of the modulation intensity, irrespective of the input amplitude. To obtain 100% modulation on AM, an input of 10 V_{pp} is required.
Sweep facilities are good, although only linear sweep is available. The sweep width may be set up to 130:1, while the sweep rate and range may both be set on the main and secondary generators. Both start and stop frequencies may be displayed.
A voltage-controlled frequency (VCF) input is provided at the rear of the instrument. This input allows large sweep-widths or different sweep functions to be obtained.

Frequency counter. The input to the counter may be obtained internally or from an external source, making the GFG-813 a dual-purpose instrument. The 6-digit display provides accurate readings and compares favourably with the 4- or 5-digit displays normally found on instruments in this price range.
Short-term accuracy of the time base is reasonable at ±10 p.p.m. However, since the time-base crystal is mounted close to a heat sink, the long-term accuracy may not be so good.
Gate times may be selected between 0.01 and 10 seconds, and this enables a good resolution to be achieved at most frequencies.
The frequency range is limited to 0.1 Hz to 30 MHz.
Accuracy and ease of use of the counter are good and make setting the main generator significantly easier and more accurate than with the more usual calibrated rotary control. Setting of the start/stop frequencies on the sweep function are also simplified greatly.
Used as an external counter, its performance is good compared with that of similar generators, but not with that of dedicated frequency counters. In that function, input sensitivity is < 20 mV r.m.s. up to 30 MHz. Other characteristics remain generally as stated before.

Construction. The external construction is based on a steel chassis with pressed stell covers. With the steel front panel surround and rear cover, this gives the GGF-813 a very solid construction and should enable it to operate under widely varying conditions. Even considering the instrument's price, the finish is good, although some of the metal casing (at least on the review model) could have fitted better together.
The front panel is plastic and provides a clear an unambiguous indication of the controls. The area around the LED display of the counter is very flexible, however, and as a result of this only slight pressure here visibly moves the display. A carrying strap is fitted at one side of the instrument.
Internal construction is good and is based on a number of double-sided fibre-glass PCBs that contain the main generator, modulation generator, and frequency counter. The boards are easily accessible for servicing.
Heat dissipation throughout the instrument is low and should not cause any problems.
The 27-page manual provides detailed operating and setting up information, as well as a description of the theory of operation of the instrument. Detailed circuit diagrams are not supplied, only a number of sections of these diagrams to illustrate the text.

Conclusion. The GFG-813 provides good performance and quality at a very competitive price. Its wide frequency range, modulation facilities, and triggering options are particularly impressive. It would have been helpful if a TTL output had been provided. A lower level of distortion on the modulation generator would also have been welcome. These deficiencies, however, do not really mar the instrument's overall performance.
Consequently, the GFG-813 is ideal for use in applications where normally much more expensive generators would have to be used. It is a particularly good choice for users in the educational sector.

The review model of the GFG-813 was supplied by Flight Electronics Ltd, Flight House, Ascupart Street, Southampton SO1 1LU, Telephone (0703) 227721. This company distributes a wide array of products, ranging from a transputer add-on board for BBC and IBM micros, and a series of logic analysers, to a range of test equipment made by GW, a Taiwanese manufacturer.

The GW range of function generators includes:
GFG-8015F: 0.2 Hz to 2 MHz; variable d.c. off-set; symmetry control; distortion < 1%; RRP £139, excl. VAT.

GFG-2D: 0.2 Hz to 2 MHz; digital frequency read-out; other characteristics similar to those of GFG-8015F; RRP £165, excl. VAT.

GFG-8016D: similar specification to GFG-8015F but with 6-digit counter; RRP £215, excl. VAT.

GFG-8016S: 0.2 Hz to 2 MHz; frequency modulation; independent setting of modulation time and frequency; built-in sweep function; distortion < 1%; RRP £180, excl. VAT.

GFG-8019: similar to GFG-8016S but with 6-digit frequency counter and internal/external AM or FM; RRP £259, excl. VAT.

NEWS

Lucas acquires Data Laboratories

Lucas CEL Instruments has acquired Data Laboratories, the Mitcham-based manufacturer of Digital Waveform Recorders.
The acquisition is in line with the strategic growth objectives in electronic measurement and control and in fluid power distribution of Lucas Industrial Systems, the parent company of Lucas CEL Instruments. Through internal growth and acquisitions, the annual sales of the Lucas Group have increased threefold to over £150 million in the past three years.
Lucas Industrial Systems • Edgbaston House • 3 Duchess Place • Hagley Road • Edgbaston • BIRMINGHAM B16 8NH.

Eurologic Systems

A new Dublin-based company, Eurologic Systems, has been formed to increase the presence of, and support to, American companies importing their Q-bus board-based products into Europe.
John Maybury, managing director of the new company, believes that the growth in demand for board-based products had led to an influx of equipment into Europe by companies that do not have the capability of providing the necessary support.
Eurologic Systems • Chamco House • SHANKILL • Co. Dublin • Ireland.

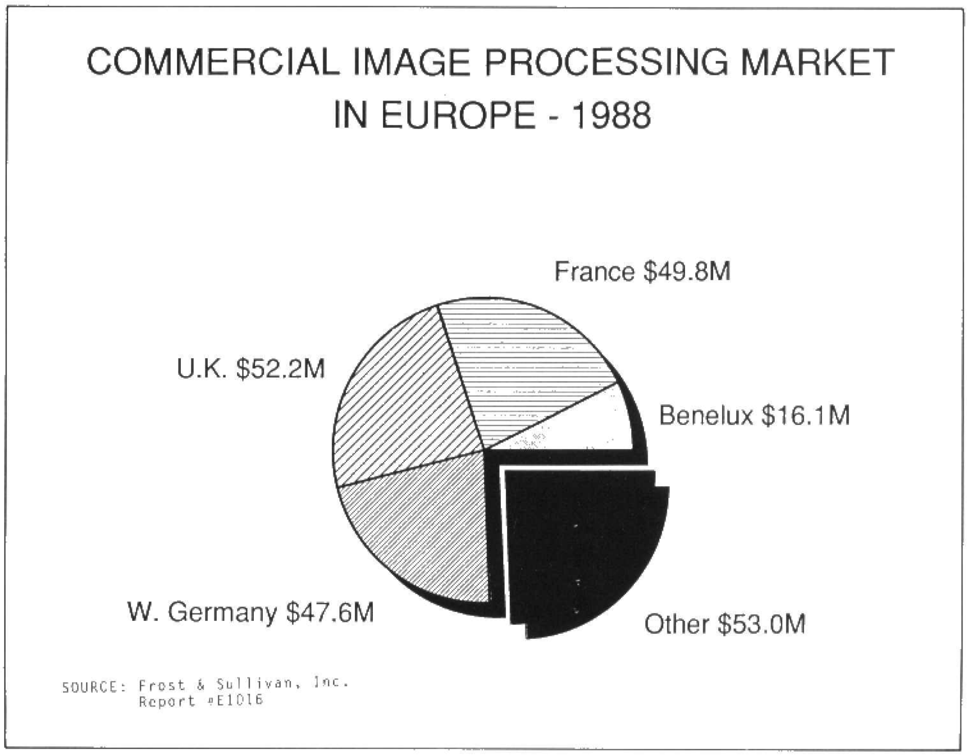


Image processing market growing

From checking facial wrinkles, before and after treatment with creams, to checking size and number of asbestos fibres caught by filters: uses for image processing are increasing rapidly. Researchers can now study in detail the shape and density of cancer cells. An advertising agency can manipulate the image of a young woman in a swimsuit from resting in a curved hammock to show her prone on the beach.
*Commercial Image Processing Market in Europe** states that the hardware and software for image processing and analysis constituted a £100 million market in western Europe in 1987. It predicts that this market will rise to around £275 million by 1992.
Market analysis report E1016 from Frost & Sullivan • Sullivan House • Grosvenor Gardens • LONDON SW1W 0DH.

A MICROPROCESSOR-BASED INTELLIGENT MULTI-FUNCTION TEST INSTRUMENT

by Dr. D.P. Mital
School of Electrical and Electronic Engineering, Nanyang Technological Institute, Singapore.

A high precision, intelligent, test instrument is described that offers ten measuring functions: DC and AC voltages, DC and AC current, resistance, capacitance, frequency, digital counter, data logging and phase measurements. The system is intelligent enough to automatically range itself for proper measurements, and is capable of providing statistical functions such as calculation of mean and standard deviations, which are useful for low-frequency measurements.

The researcher or technician involved in project development usually requires many instruments to perform various common measurements. Often, a lot of precious time is wasted in connecting and disconnecting these instruments. Also, handling and storage problems soon arise in the work area as the number of instruments increases.

Recently, there has been considerable interest in integrating many functions in one compact unit (Ref. [1], [2]). The industry has been very receptive to this idea. This article presents a multifunction unit which has some intelligence, and integrates many common measuring functions. Accuracy, reliability and low cost are also important considerations. The proposed system is developed around the Type 8086 16-bit microprocessor from Intel, and is capable of performing operations which include that of a common multimeter, capacitance meter, phase meter, frequency meter, digital counter and data logger. Autoranging and repetitive modes for averaging are also available. The measuring function and, optionally, the range, is selected by means of a 16-key membrane keyboard, and measurement results are sent to a 40-character LC display. Since the system has intelligence, on-line data and results may be stored semi-permanently, and retrieved when required. This feature makes the system highly suitable for real-time interactive measurement and control applications. A multiple number of readings can also be recorded in a fixed time interval.

For reasons of speed and efficiency, the system software has been written in 8086 assembly language. The software was written and debugged using an IBM PC/AT and an HP6400 development system.

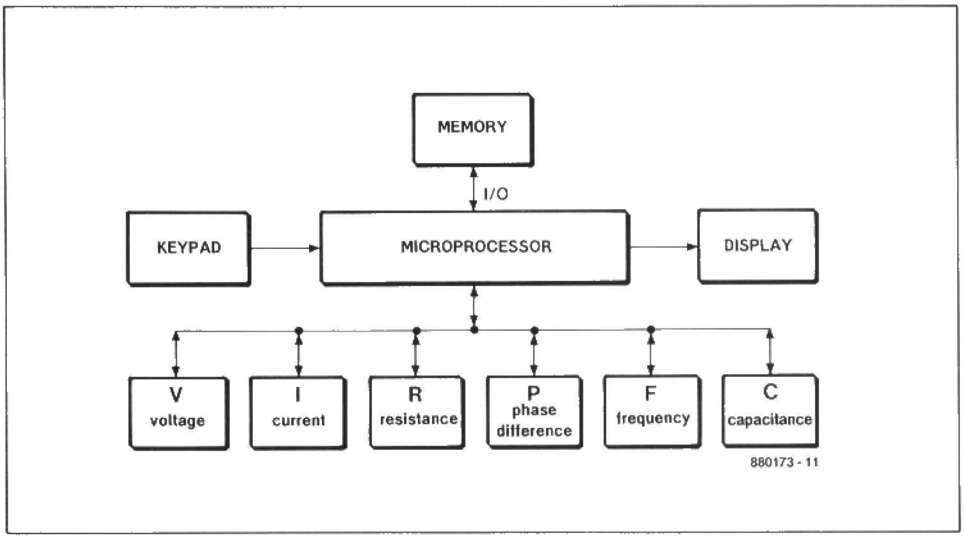


Fig. 1. Block diagram of the multifunction test instrument.

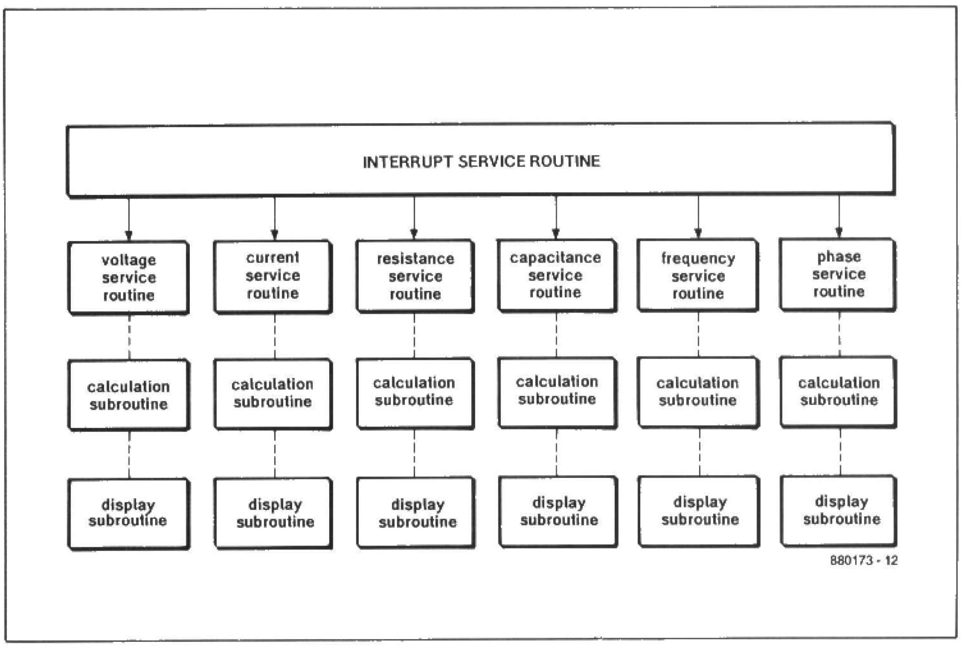


Fig. 2. General structure of the system software.

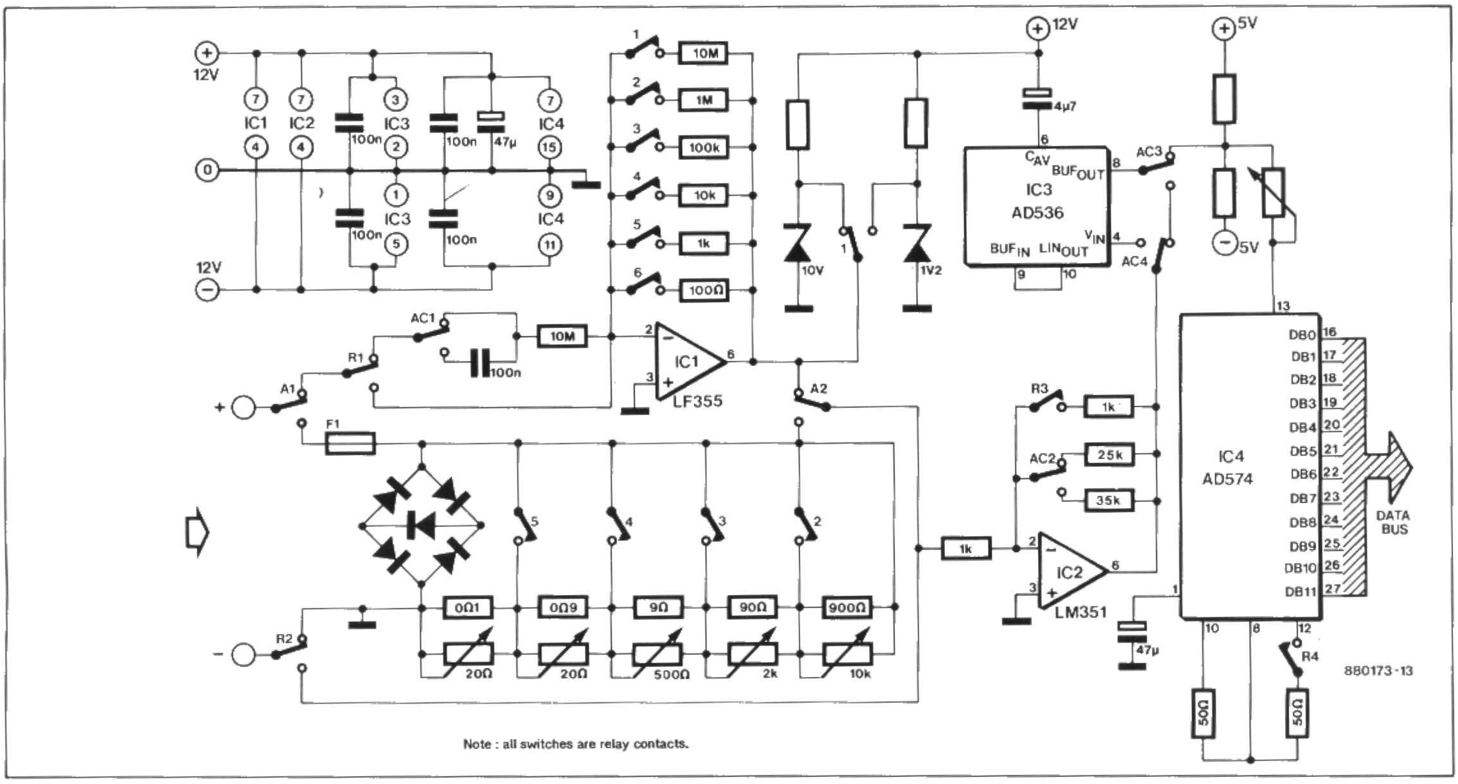


Fig. 3. Circuit diagram of the multimeter section.

Multifunction system

Figure 1 shows the block diagram of the proposed system. Analogue input signals are sampled and converted to digital data. When this is done, the microprocessor strobes the relevant block, and data processing commences. Results are read on the LC display. The keypad, which operates in an interrupt structure, provides the user with minimum control of the instrument as explained above.

Current and voltage meter

Signals for V and I measurements are first scaled internally to prevent their exceeding the maximum input specification of the A-D converter (±5 V). After scaling, the DC signal is fed direct to the sampling circuit, while the AC signal is fed to an RMS-to-DC converter, and then to the sampling circuit. The ADC awaits the strobe signal from the microprocessor to start conversion. Converted data is immediately read via the data bus. A two-pole, microprocessor-controlled, change-over switch selects the appropriate measurement function. Signals exceeding 200 mV are attenuated, and later amplified to TTL level. The ranges for voltage and current measurments are 20 mV to 1000 V and 20 μA to 2 A respectively.

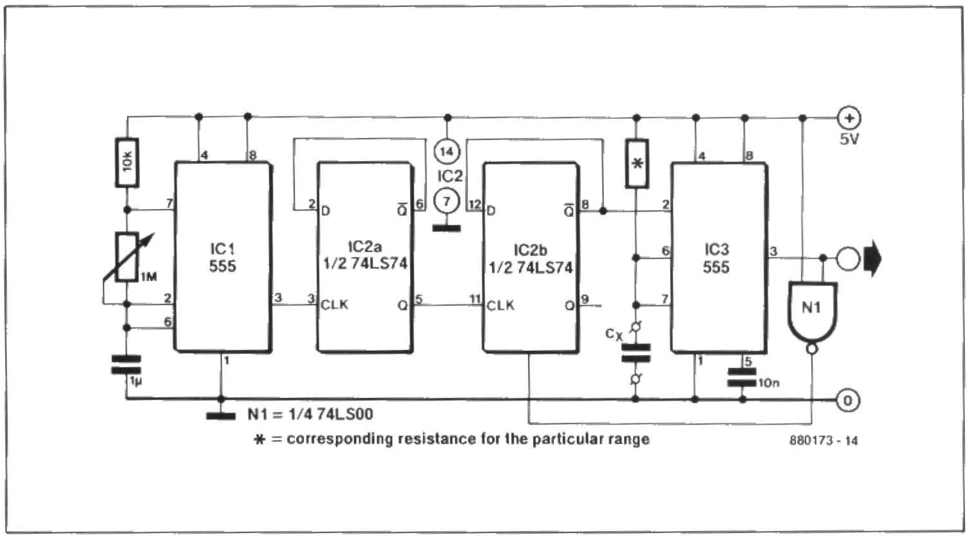


Fig. 4. Schematic diagram of the capacitance meter section.

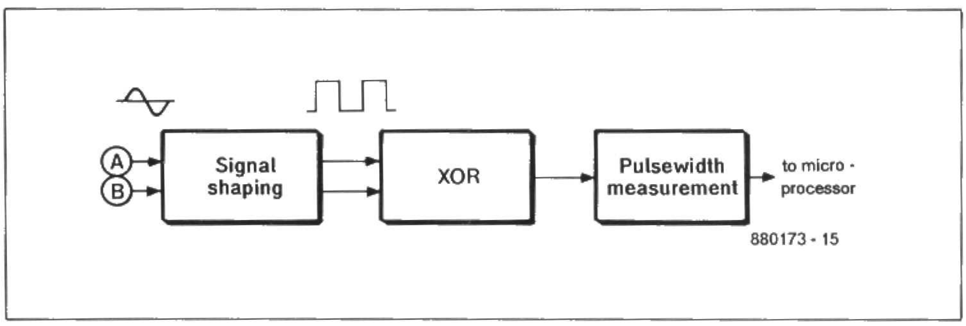


Fig. 5. Block diagram of the phase meter.

Resistance meter

For resistance measurement, two voltage references are used. This is done to extend the measurement range. One reference voltage is used in the autoranging mode. The resistance sampling circuit shares the first stage opamp with the voltage sampling circuit. The output voltage of the comparison block is proportional to the unknown resistance, for which six ranges are available. The circuit diagram of the multimeter section is shown in Fig. 3.

Capacitance meter

Capacitance measurement is based on pulse-width modulation techniques. Again, six ranges are provided. The basic circuit diagram of Fig. 4 shows that the charging and discharging properties of capacitors are used to determine capacitance with the aid of two timers Type 555, and two bistables. The timers are configured to function as monostable multivibrators.

Phase meter

Phase detection first requires the conversion of sinusoidal input signals to rectangular waves as shown in the block diagram of Fig. 5. The phase difference between the input signals can be computed by the CPU because it is proportional to the pulse-width of the signal supplied by the XOR gate.

Frequency meter

Frequency measurement is similar to phase detection. The block diagram of Fig. 6 shows that the input signal is made rectangular before being applied to a combinational circuit and a programmable divider. These two circuits control a 32-bit counter. The divider, which is initially set to a factor of ÷2, stops the counter on the rising edge of the second pulse. This completes the first phase of the measurement. The CPU calculates the period and estimates the number of pulses needed from the input signal for 0.1 s of sampling time. The divider is then programmed accordingly. The count procedure is similar for the second sample of the imnput signal, but this time the counter stops after a known number of pulses, as determined by the CPU and executed by the divider. The measurement principle adopted allows signal frequencies to be determined with high precision.

Event counter

Event measurement is essentially similar to that for frequency, and shares a part of the relevant circuitry. Only counter start and stop signals are needed, which are provided by the measuring circuit.

Data logger

Data logging is purely a software function. Displayed data is stored in memory when the STROBE key is actuated on the keypad. Key RECALL may be pressed for data to appear on data lines and on the LC display. The system is capable of storing hundreds of data readings sequentially. Last-in data can be recalled first (LIFO stack). The flowchart of the data logger function is given in Fig. 7.

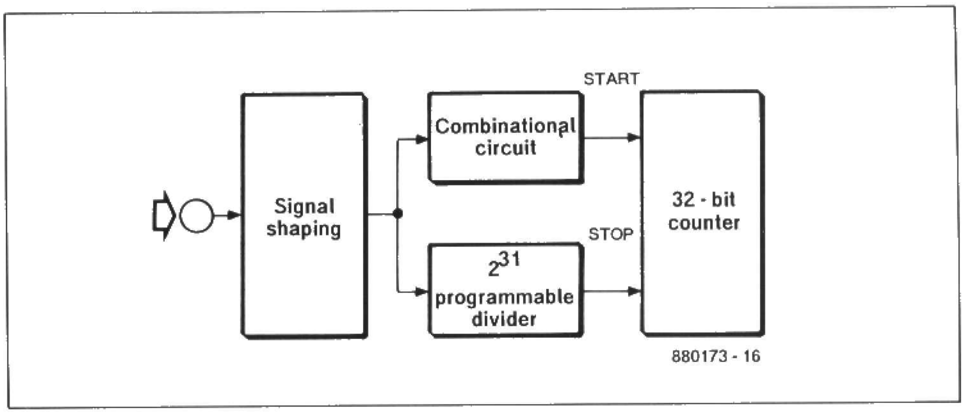


Fig. 7. Flowchart of the data logging routine

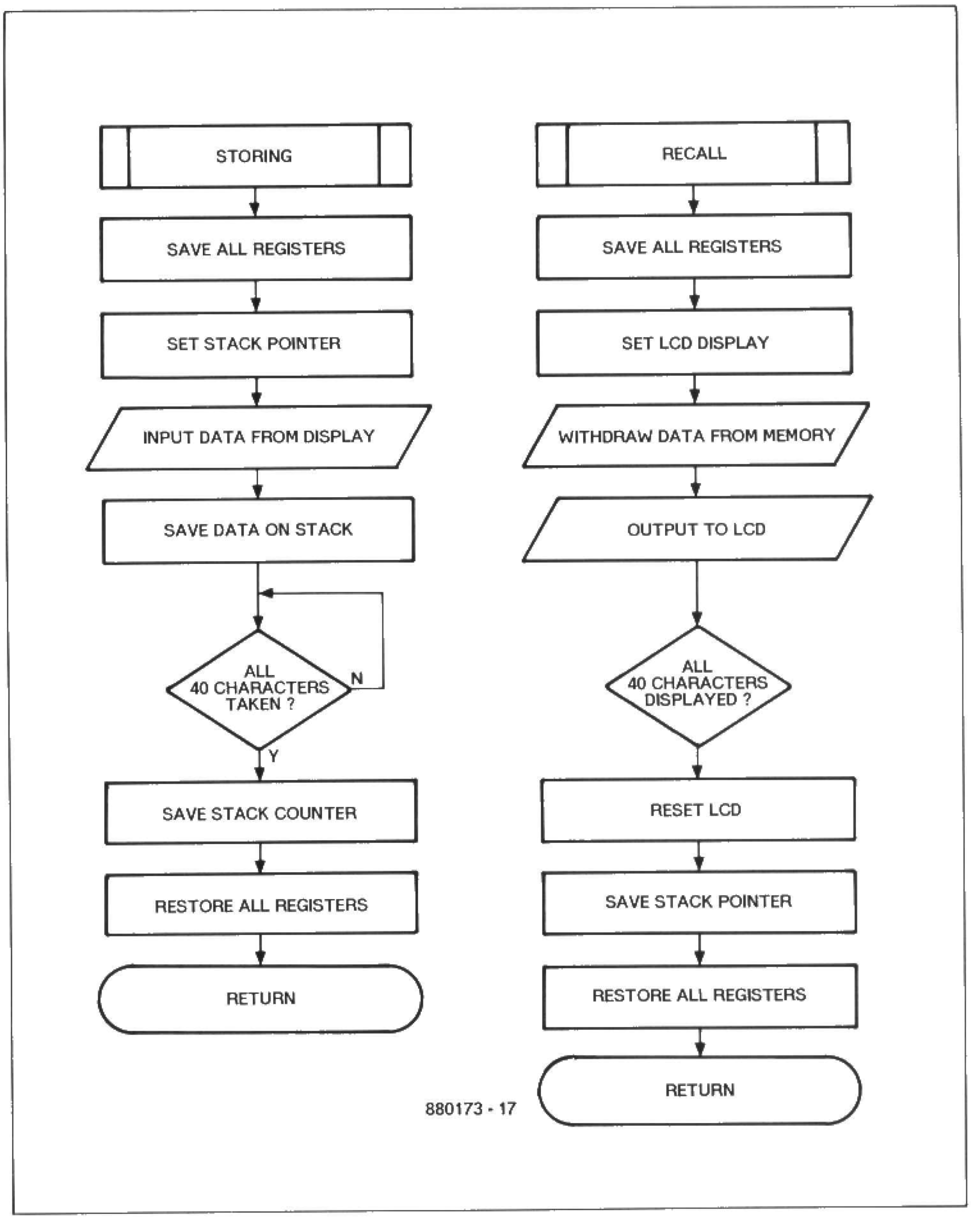


Fig. 6. Block diagram of the frequency meter.

Software development

The following description is intended to give a basic idea of the operation of the control software for the instrument. It is assumed that this is set to capacitance measurement. Pressing the CAPACITANCE key causes the interrupt servicing routine to be activated. After the interrupt source is determined, the service routine passes control to the capacitance measurement program, which arranges the necessary switching and sampling of the data. Repetitive reading may be used for calculation of mean and standard deviations. The calculation routine is called to process the available data, followed by the display routine to provide legible results.

Every measuring function has a control program, which is called up by pressing the appropriate key. Control programs perform the necessary switching in the measurement circuits, and manipulate available data. First, the range flag is checked, and the hardware is controlled accordingly by autoranging software to ensure optimum accuracy before data is accepted. The control software is also involved in the repetitive mode of operation. A simplified flowchart of the control programs is shown in Fig. 8.

Autoranging is not used during measurement of frequency and phase, since in these modes data samples are taken twice: first for estimating the order of magnitude, and then for the actual measurement. The flowchart of the frequency control program is given in Fig. 9.

The operation of the test instrument is

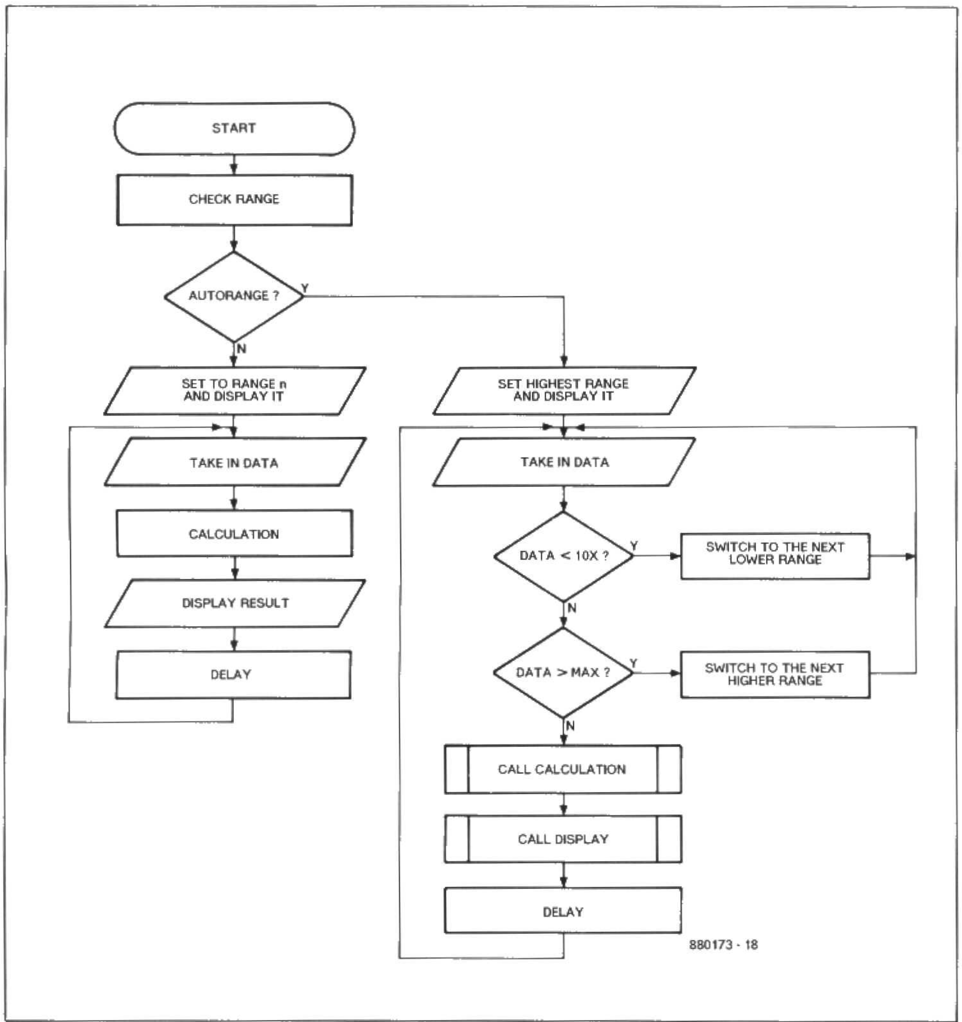


Fig. 8. General flowchart of the control programs.

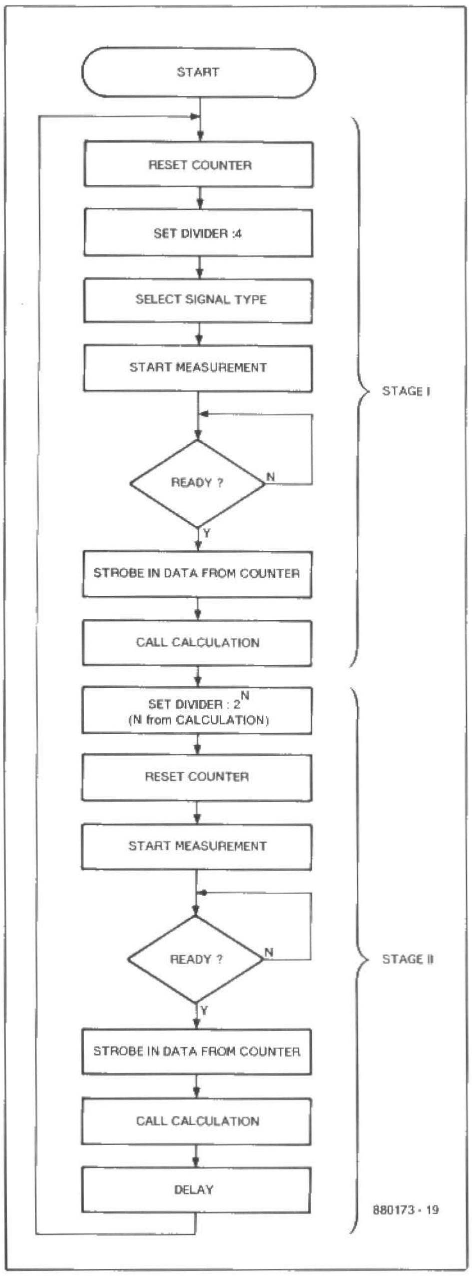


Fig. 9. Flowchart of the frequency measurement program.

further co-ordinated by software modules written for each function. These modules each consist of a function service routine, a calculation routine and a display routine.

System hardware

The wiring diagram of Fig. 10 shows that the hardware of the CPU card basically consists of a 8086 CPU with 64 Kbyte of memory (RAMs and EPROMs), buffers (74LS245 and 8286), latches (74LS373 and 8282) and decoders (74LS138). A total of 64 I/O ports is used. These are addressable from 00_H to $3F_H$ as shown in Table 1. The 4×4 key membrane keypad utilizes a Type 74C922 encoder. The 1 line × 40 character LC display is of the dot-matrix type. It is connected to data I/O lines DB0-DB15 through 74LS245 buffers, which form port numbers 10_H and 11_H.

Table 1.	Port addresses
V/I/R BOARD	00-07
A-D data input	00
stautus check	01
A-D control	02
Range control	04
Function control	06
FREQUENCY BOARD	08-0F
Counter setting	08
Divider setting	09
Ready input	0A
Start output	0C
Counter data input	0E
CAPACITANCE & PERIPHERAL BOARD	10-17
Display control	10
Display data	11
Input data	12
C range control	14

All addresses in hexadecimal.

Experimental results and conclusion

Results of all measuring functions of the instrument were compared with existing, high-precision, laboratory equipment. In all cases, deviations from the standard equipment remained well within 2%. Phase, frequency and event count measurements were on average within 0.5% accuracy. Table 2 shows the results of a few comparative measurements taken with the proposed multifunction instrument.

The author believes that it is worthwile to spend time on further development of the multifunction instrument, whose basic lay-out has been discussed here. The design of the instrument shows that test & measurement equipment is heading in the same direction as much other electronics equipment, i.e., towards high-level integration.

Table 2. Experimental results

Voltage		Current		Resistance		Capacitance	
Standard	Measured	Standard	Measured	Standard	Measured	Standard	Measured
5 V	4.98 V	4.8 V	4.68 V	1.5 kΩ	1.506 kΩ	10 pF	10 pF
50 V	49.44 V	12 V	11.92 V	10 kΩ	10.04 kΩ	1000 pF	1001 pF
120 V	119.12 V	50 V	48.81 V	47 kΩ	47.02 kΩ	0.1 μF	0.099 μF

For AC measurements RMS values are recorded.

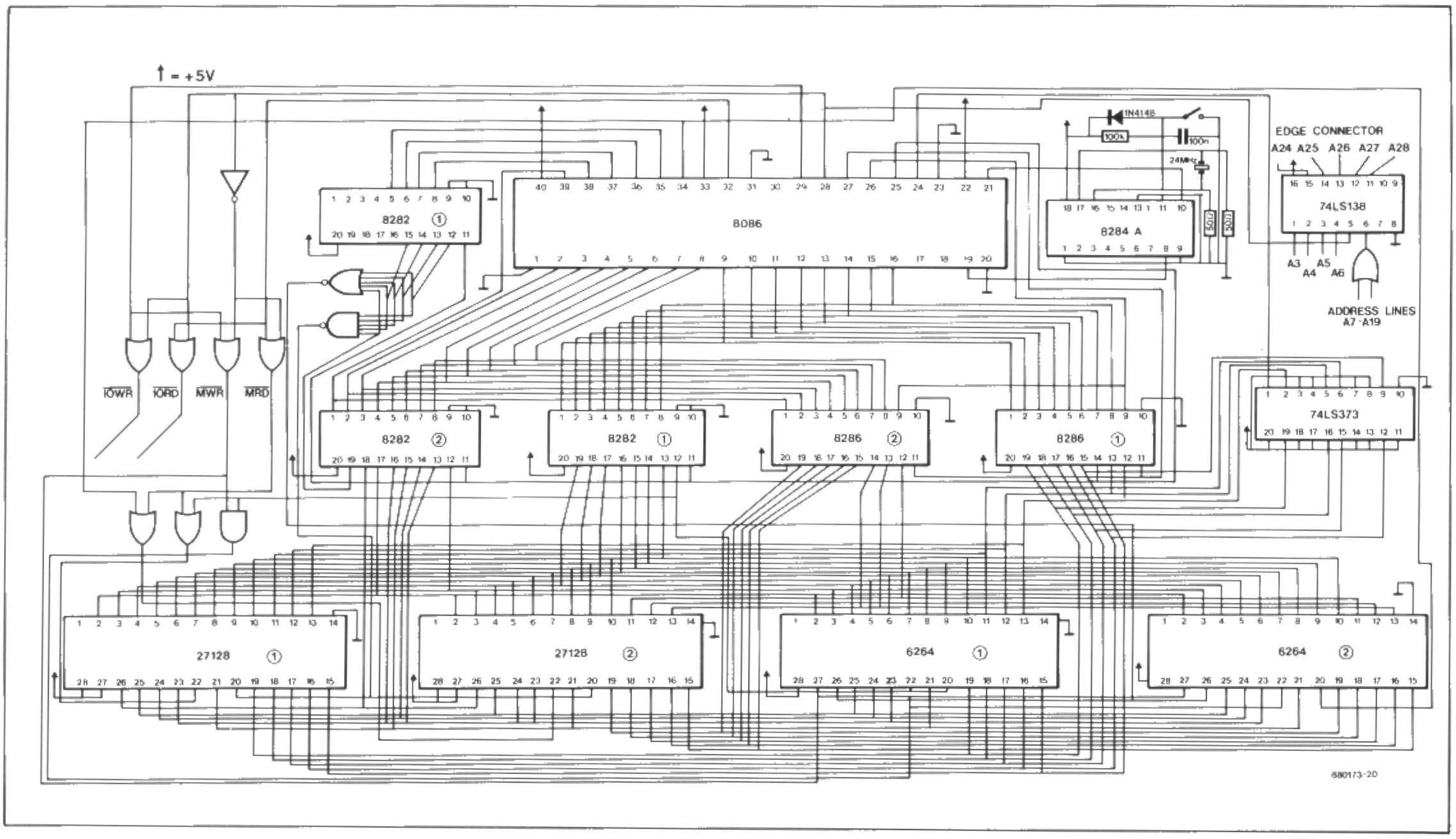


Fig. 10. Wiring diagram of the microprocessor board in the multifunction instrument.

Acknowledgements:
the author would like to thank Mr Bay Way Yee and Miss Chong Mong Tan for developing and testing the system, and professor Brian Lee, Dean of the School of Electrical and Electronic Engineering, for providing facilities for carrying out this work.

References:
(1) Trautman J. and Desjardin L.: *A portable low-cost high performance digital multimeter.* HP Journal, Vol. 34, no. 2, 1983.
(2) Steever S. et al.: *Seven-function systems multimeter offers extended resolution and scanner capabilities.* HP Journal, Vol. 37. no. 2, 1986.
(3) Walter A. and Singh A.: *The 8086 Microprocessor Architecture, software and interfacing techniques.* Prentice-Hall, 1986.
(4) *Macro assembler.* (IBM personal computer language series) Microsoft, 1985.

RADIO & TV NEWS

DEC's winning vision?

Digital Equipment Corporation boasts that connecting IBM products to a DEC system is easier than hooking up IBM products with one another. According to *Digital Equipment Corporation Marketing Strategy to 1992**, this is not an idle boast.

Digital offers its clients a vision of a single network throughout a company, from desktop computer to the corporate centre. Sales of products and services in 1987 amounted to $9.4 billion and are forecast to rise to $25.1 billion by 1992. Although DEC's strength, as far as processing power is concerned, has so far been in the middle range, the company is now assaulting IBM's mainframe supremacy with its VAX8800 series, introduced last March. The 8800 has a computing power of 24 MIPS (million instructions per second).

* Market analysis report A1944 from Frost & Sullivan • Sullivan House • 4 Grosvenor Gardens • LONDON SW1W 0DH

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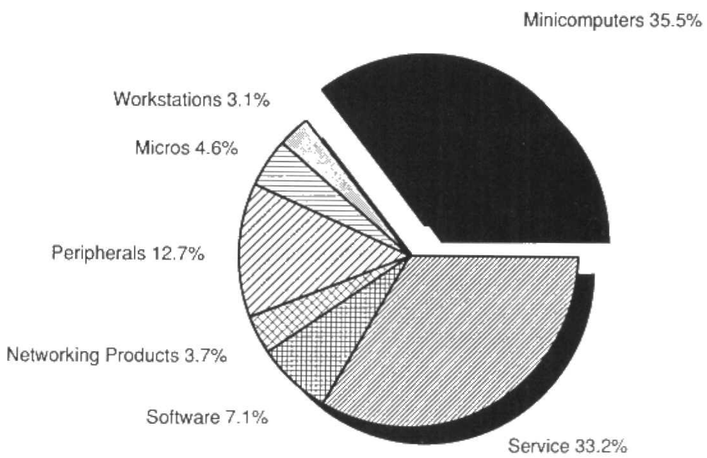

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Readers who wish to make their own PCBs (for private and personal use only) may in many, but not all, cases receive the relevant drawings free of charge by ordering these on the order form opposite and enclosing a stamped addressed envelope (preferably 9 × 6 in or 230 × 150 mm). These drawings may also be supplied on film priced at £1.00 each plus p&p.

	No.	Price (£)	VAT (£)
DECEMBER 1987			
Frequency meter	87286-A	12.50	1.88
LCD VU meter	87505	6.75	1.01
	87520	6.75	1.01
JANUARY 1988			
DCF77 Receiver and Frequency Standard	86124-A	8.70	1.31
	87105	Not available	
Stereo limiter	87168	7.25	1.09
Light-powered thermometer	87188	6.75	1.01
Switch-mode PSU	880001	5.00	0.75
FEBRUARY 1988			
Intelligent time standard	86124-2	7.15	1.07
Infra-red headphones	87640	6.10	0.92
Prescaler for frequency meter	880005	9.25	1.39
MARCH 1988			
Slave indication unit	87104-1	10.50	1.58
for I.T.S	87104-2	10.50	1.58
Computer-controlled slide fader	87259	16.00	2.40
Low-noise preamplifier	880041	6.50	0.98
for FM receivers	880042	5.00	0.75
Signal divider for satellite TV receivers	880067	5.00	0.75
APRIL 1988			
Stereo sound generator	87142	7.25	1.09
Fuzz unit for guitars	87255	6.50	0.98
Active loudspeaker system	880030	7.50	1.13
Tuneable preamplifiers	880044	6.25	0.94
for VHF & UHF TV	880045	5.50	0.83
MAY 1988			
Plotter	87167	11.50	1.73
Balanced line driver and receiver	87197	10.50	1.58
VLF convertor	880029	5.75	0.86
JUNE 1988			
Microcontroller-driven power supply	880016-1	19.00	2.85
	880016-2	12.50	1.88
	880016-3	15.00	2.15
	880016-4	0.75	0.11
I/O extension card for IBM PC	880038	28.75	4.31
Wideband active aerial	880043-1	6.00	0.90
for SW receivers	880043-2	4.75	0.71
HF operation of fluorescent tubes	880085	9.75	1.46
JULY/AUGUST 1988			
Transmission & reception	86019	Not available	
of RTTY	87686X	Not available	
Video distribution amplifier	87466	Not available	
Power switch for cars	87467	Not available	
Electronic sand-glass	87406	6.60	0.99
Fruit machine	87476	Not available	
I/O extension card for IBM	880038	28.60	4.29
(with gold-plated connector)			
Frequency read-out for SW receivers	880039	18.40	2.76
Car tilt alarm	884002	Not available	
Universal prototyping board	884013	10.45	1.57
Simple transistor tester	884015	4.60	0.69
Lead-acid-battery charger	884019	Not available	
Automatic volume control	884023	Not available	
Universal SMD-to-DIL adaptors	884025	2.60	0.39
Five-band graphic equalizer	884049	7.95	1.20
AM calibration generator	884054	Not available	
Stepper motor driver	884076	5.85	0.88
150 W AF power amplifier	884080	4.20	0.63
Simple 80 m RTTY receiver	886034X	8.15	1.23
Printer sharing box	884030	Not available	
SEPTEMBER 1988			
Fast NiCd charger	87186	6.10	0.92
64 K RAM for MSX	87311	15.95	2.39
µP-controlled radio synthesizer	880120-1	14.00*	2.10
	880120-2, 880120-3	10.00*	1.50

* These 3 prints may be purchased as a single package under reference 880120-9 at the special price of £17.50 (VAT £2.63). This offer closes on 30 November 1988.

	No.	Price (£)	VAT (£)
Self-inductance meter	880134	8.30	1.25
OCTOBER 1988			
Centronics interface for slide fader	880111	7.75	1.16
Preamplifier for purists	880132-1	5.90	0.89
	880132-2	12.25	1.84
Ultrasonic distance meter	880144	7.75	1.16
Peripheral modules for	880159	5.00	0.75
BASIC computer	880162	5.00	0.75
	880163	5.40	0.81
Transistor curve tracer	886087	4.60	0.69
NOVEMBER 1988			
Tracker-ball for Atari ST	87260	Not available	
Simplified time-signal receiver	87513	7.40	1.11
LFA-150 — a fast	880092-1	8.45	1.27
power amplifier	880092-2	7.70	1.16
Harmonic enhancer	880167	6.30	0.95
Portable MIDI keyboard	880168	7.85	1.18

Evening on the planet Oldana, as the Maplin Juggertrain thunders along the highway; captured on canvas by galaxy famous artist Lionel Jeans and featured on the cover of the new Maplin Catalogue.